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(54) **SYSTEM FOR MANAGING VENTILATOR OPERATION**

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CPC ***A61M 16/1005*** (2014.02); ***A61B 5/002*** (2013.01); ***A61B 5/412*** (2013.01); ***A61M 16/00*** (2013.01); ***A61M 16/0003*** (2014.02); ***A61M 16/0051*** (2013.01); ***A61M 16/10*** (2013.01); ***G06F 19/3418*** (2013.01);
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USPC 128/204.21, 204.23, 200.24, 204.18
See application file for complete search history.

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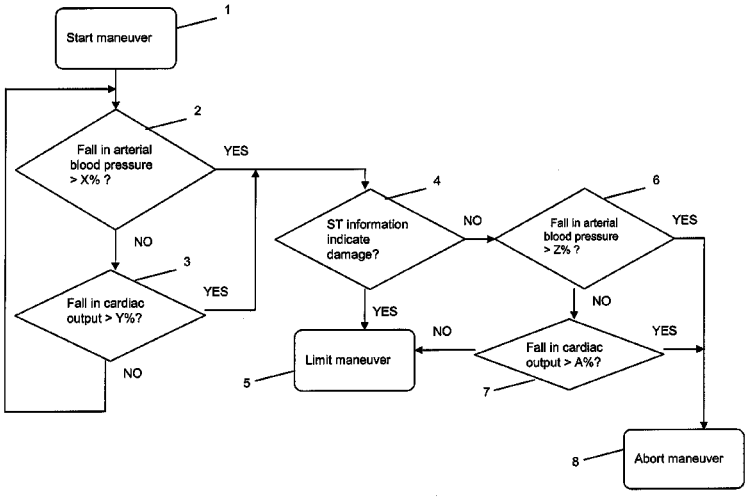
(57) **ABSTRACT**

A method for managing patient ventilator operation includes receiving data representing one or more hemodynamic parameters. In response to the received data representing the one or more hemodynamic parameters, one or more commands are provided for adaptively altering ventilator operation.

20 Claims, 6 Drawing Sheets



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A61M 16/16	(2006.01)

(52) **U.S. Cl.**

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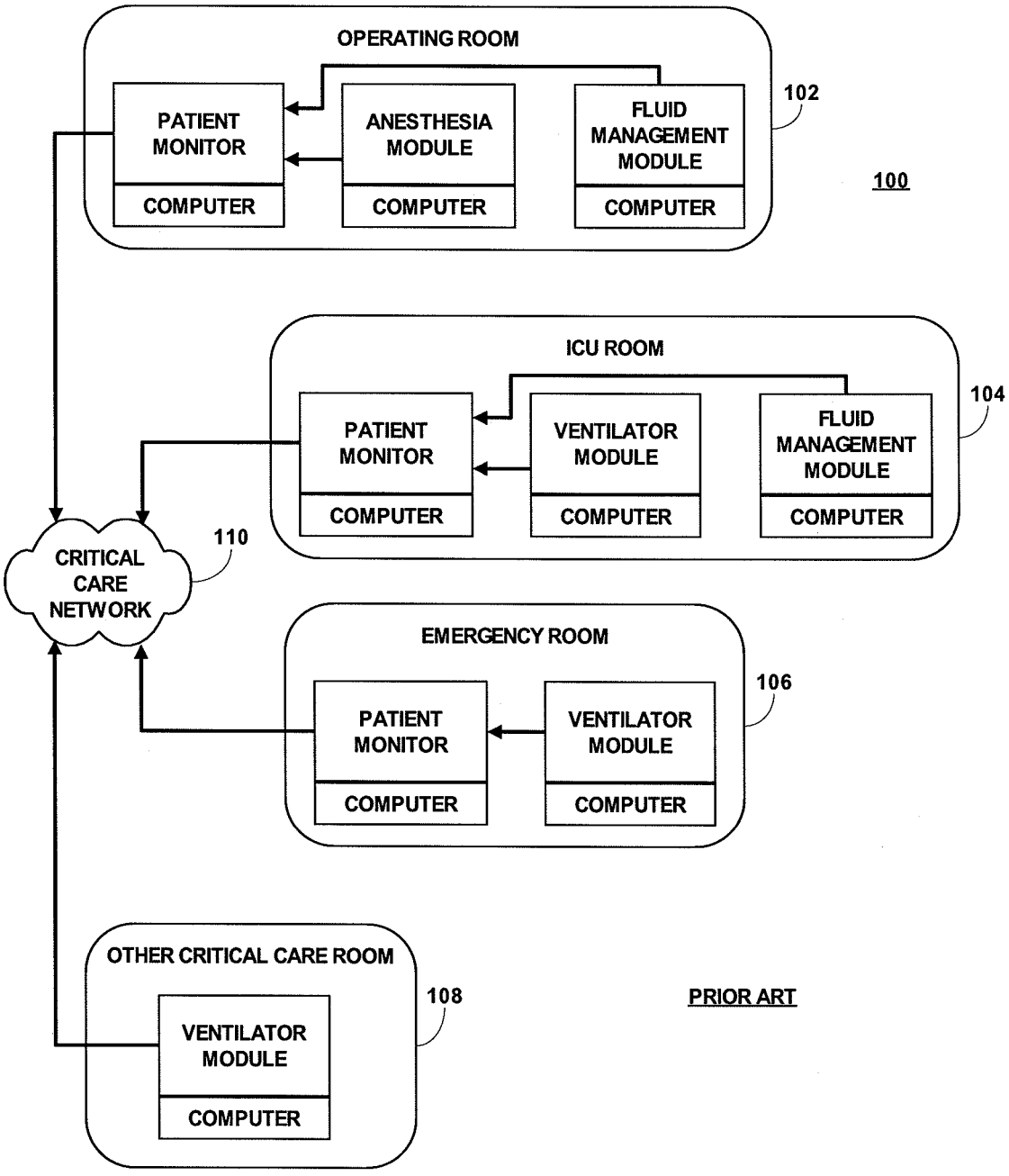
OPERATING ROOM
PATIENT MONITOR
COMPUTER
ANESTHESIA MODULE
COMPUTER
FLUID MANAGEMENT MODULE
COMPUTER
102
100
ICU ROOM
PATIENT MONITOR
COMPUTER
VENTILATOR MODULE
COMPUTER
FLUID MANAGEMENT MODULE
COMPUTER
104
CRITICAL CARE NETWORK
110
EMERGENCY ROOM
PATIENT MONITOR
COMPUTER
VENTILATOR MODULE
COMPUTER
106
OTHER CRITICAL CARE ROOM
VENTILATOR MODULE
COMPUTER
108
PRIOR ART

Fig. 1

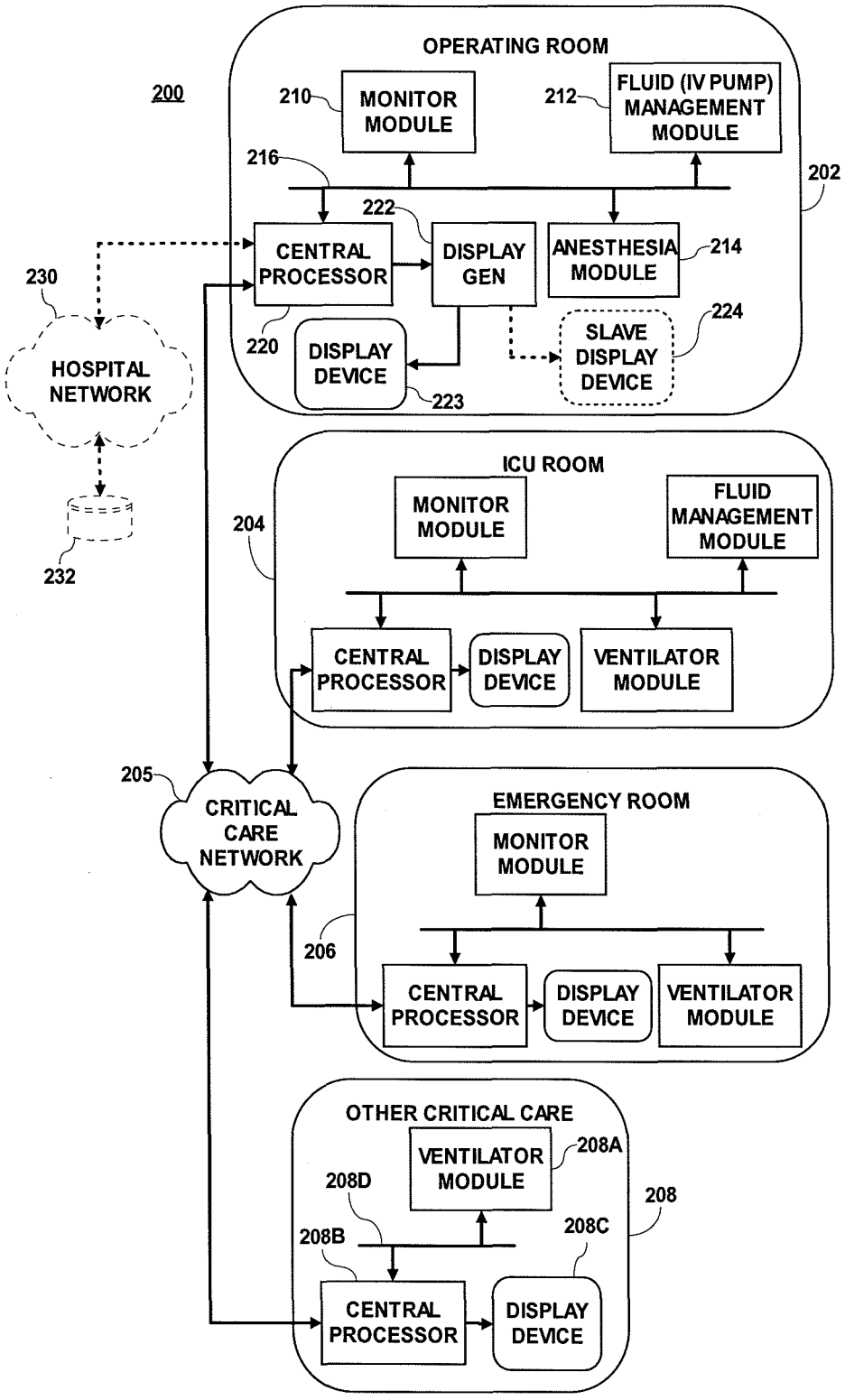
200
OPERATING ROOM
210
MONITOR MODULE
212
FLUID (IV PUMP) MANAGEMENT MODULE
216
202
222
CENTRAL PROCESSOR
DISPLAY GEN
ANESTHESIA MODULE
214
230
220
DISPLAY DEVICE
223
SLAVE DISPLAY DEVICE
224
HOSPITAL NETWORK
232
ICU ROOM
204
MONITOR MODULE
FLUID MANAGEMENT MODULE
CENTRAL PROCESSOR
DISPLAY DEVICE
VENTILATOR MODULE
205
CRITICAL CARE NETWORK
EMERGENCY ROOM
MONITOR MODULE
206
CENTRAL PROCESSOR
DISPLAY DEVICE
VENTILATOR MODULE
OTHER CRITICAL CARE
VENTILATOR MODULE
208A
208D
208
208B
208C
CENTRAL PROCESSOR
DISPLAY DEVICE

Fig. 2

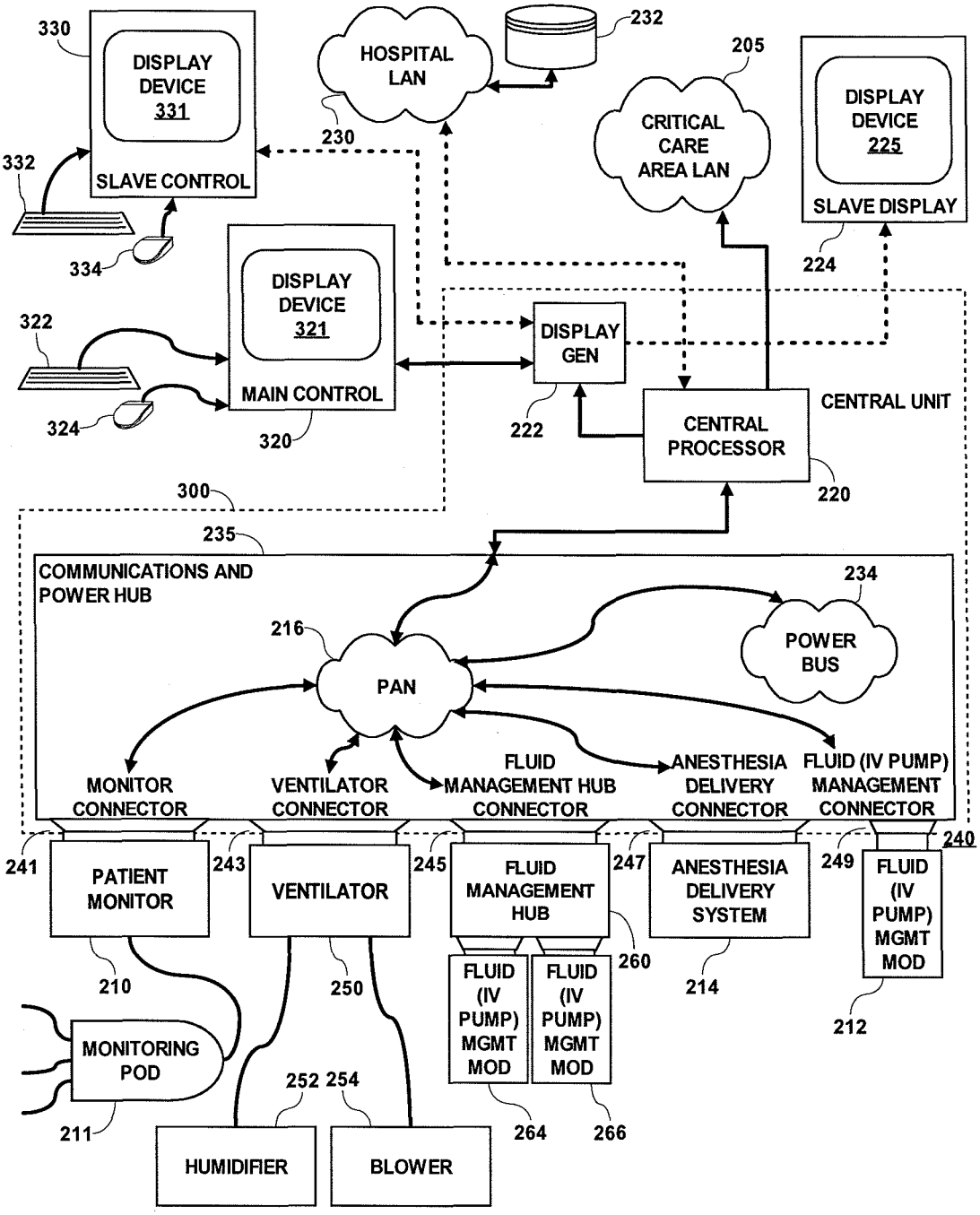
330
DISPLAY DEVICE 331
SLAVE CONTROL
332
334
HOSPITAL LAN
230
232
205
CRITICAL CARE AREA LAN
DISPLAY DEVICE 225
SLAVE DISPLAY
224
322
DISPLAY DEVICE 321
MAIN CONTROL
320
324
DISPLAY GEN
222
CENTRAL PROCESSOR
CENTRAL UNIT
220
300
235
COMMUNICATIONS AND POWER HUB
234
POWER BUS
216
PAN
MONITOR CONNECTOR
VENTILATOR CONNECTOR
FLUID MANAGEMENT HUB CONNECTOR
ANESTHESIA DELIVERY CONNECTOR
FLUID (IV PUMP) MANAGEMENT CONNECTOR
240
241
243
245
247
249
PATIENT MONITOR
VENTILATOR
FLUID MANAGEMENT HUB
ANESTHESIA DELIVERY SYSTEM
FLUID (IV PUMP) MGMT MOD
210
250
260
214
212
MONITORING POD
211
252
254
FLUID (IV PUMP) MGMT MOD
FLUID (IV PUMP) MGMT MOD
264
266
HUMIDIFIER
BLOWER

Fig. 3

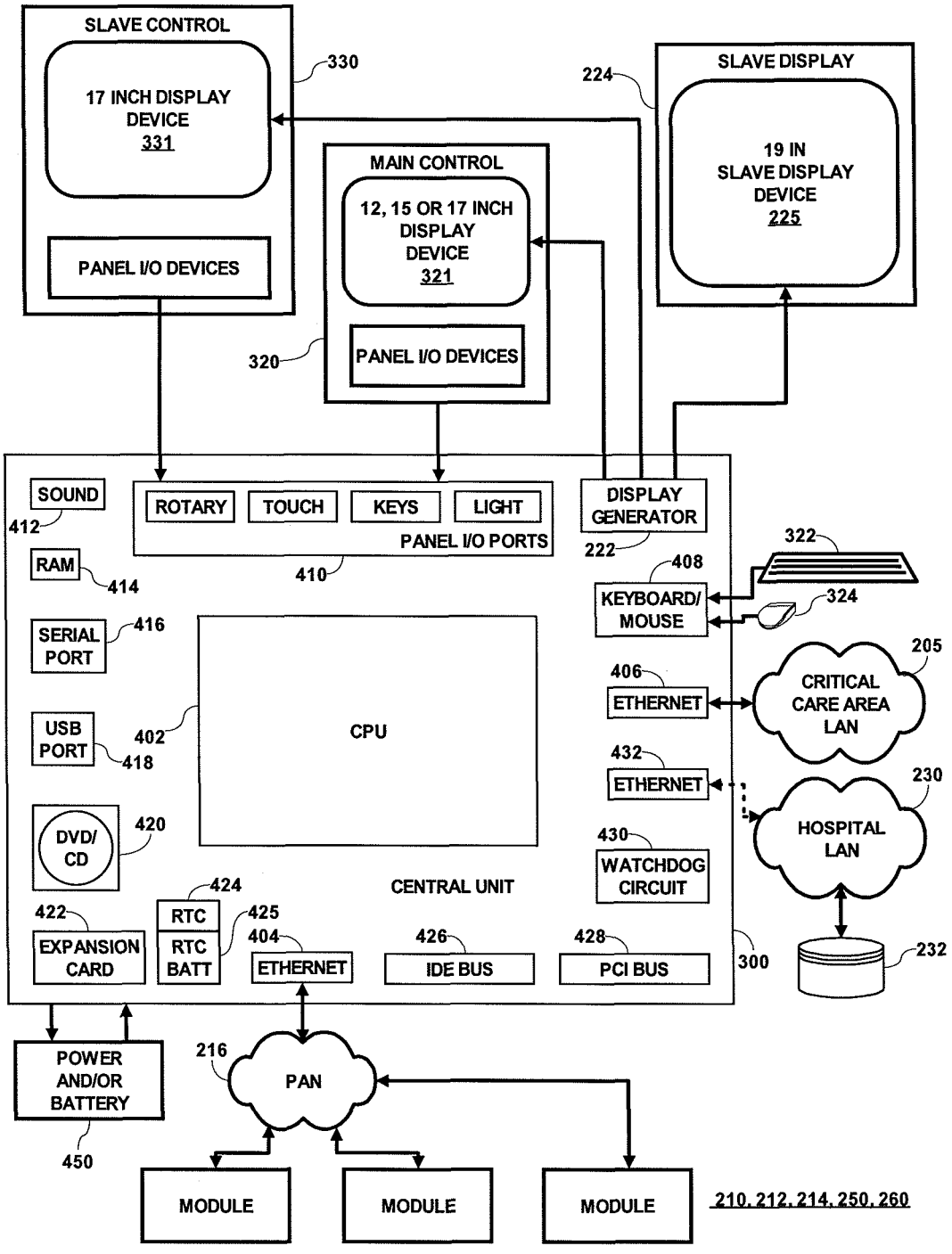
SLAVE CONTROL
17 INCH DISPLAY DEVICE 331
330
PANEL I/O DEVICES
MAIN CONTROL
12, 15 OR 17 INCH DISPLAY DEVICE 321
320
PANEL I/O DEVICES
224
SLAVE DISPLAY
19 IN SLAVE DISPLAY DEVICE 225
SOUND
412
ROTARY
TOUCH
KEYS
LIGHT
PANEL I/O PORTS
410
DISPLAY GENERATOR
222
322
RAM
414
408
KEYBOARD/ MOUSE
324
SERIAL PORT
416
CPU
USB PORT
418
402
406
ETHERNET
205
CRITICAL CARE AREA LAN
432
ETHERNET
230
HOSPITAL LAN
DVD/ CD
420
430
WATCHDOG CIRCUIT
424
CENTRAL UNIT
422
EXPANSION CARD
RTC
RTC BATT
425
404
ETHERNET
426
IDE BUS
428
PCI BUS
300
232
POWER AND/OR BATTERY
450
216
PAN
MODULE
MODULE
MODULE
210, 212, 214, 250, 260

Fig. 4

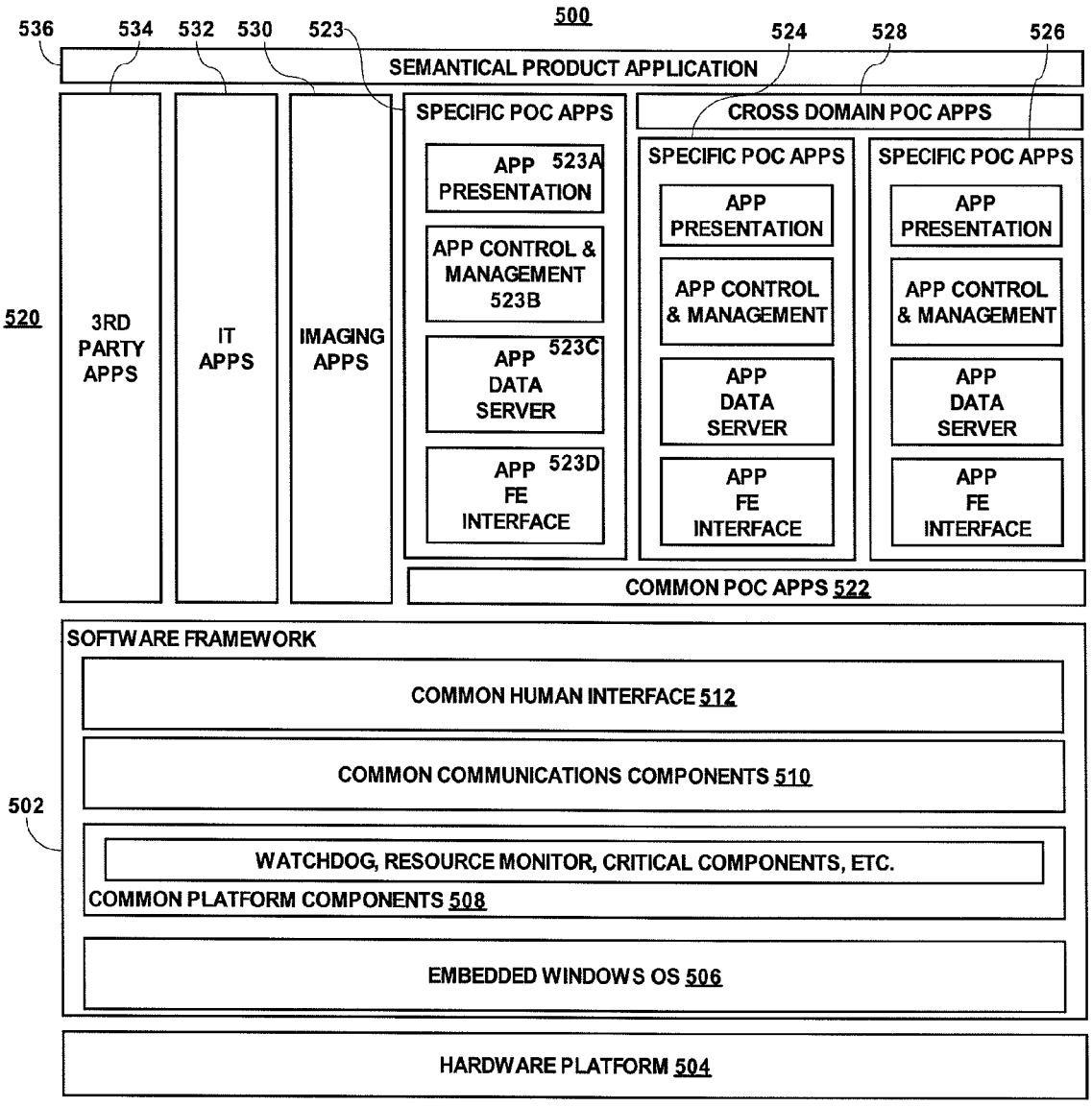
500
536
534
532
530
523
524
528
526
SEMANTICAL PRODUCT APPLICATION
520
3RD PARTY APPS
IT APPS
IMAGING APPS
SPECIFIC POC APPS
APP PRESENTATION 523A
APP CONTROL & MANAGEMENT 523B
APP DATA SERVER 523C
APP FE INTERFACE 523D
CROSS DOMAIN POC APPS
SPECIFIC POC APPS
APP PRESENTATION
APP CONTROL & MANAGEMENT
APP DATA SERVER
APP FE INTERFACE
SPECIFIC POC APPS
APP PRESENTATION
APP CONTROL & MANAGEMENT
APP DATA SERVER
APP FE INTERFACE
COMMON POC APPS 522
SOFTWARE FRAMEWORK
COMMON HUMAN INTERFACE 512
COMMON COMMUNICATIONS COMPONENTS 510
502
WATCHDOG, RESOURCE MONITOR, CRITICAL COMPONENTS, ETC.
COMMON PLATFORM COMPONENTS 508
EMBEDDED WINDOWS OS 506
HARDWARE PLATFORM 504

Fig. 5

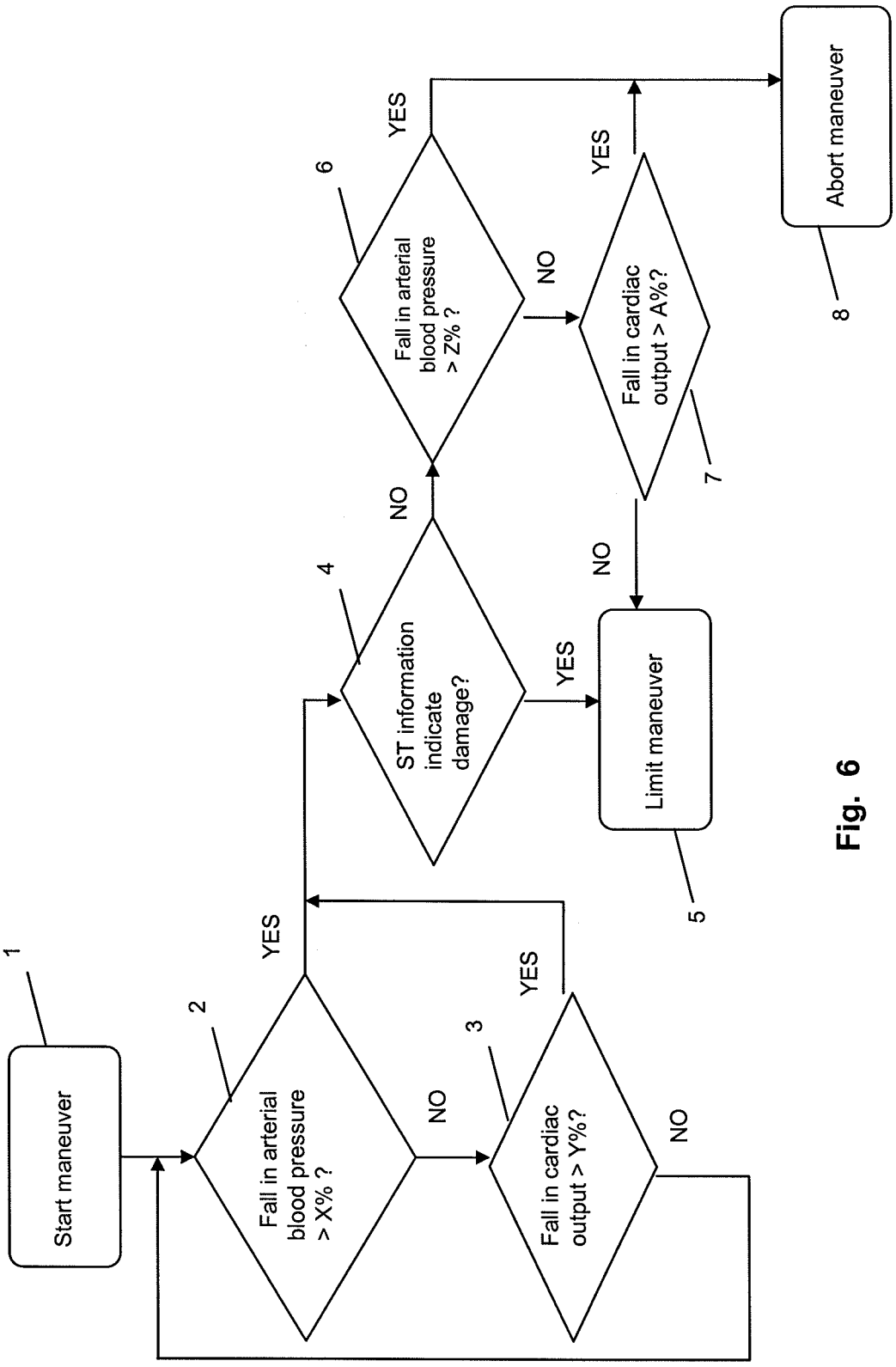
Start maneuver
1
Fall in arterial blood pressure > X% ?
2
YES
NO
Fall in cardiac output > Y%?
3
YES
NO
ST information indicate damage?
4
YES
NO
Limit maneuver
5
Fall in arterial blood pressure > Z% ?
6
YES
NO
Fall in cardiac output > A%?
7
YES
NO
Abort maneuver
8

Fig. 6

SYSTEM FOR MANAGING VENTILATOR OPERATION

CROSS REFERENCE TO RELATED APPLICATIONS

The application is a continuation-in-part of U.S. patent application Ser. No. 10/976,025 filed Oct. 28, 2004 now abandoned which, in turn, claims priority to U.S. Patent Application No. 60/519,300 filed on Nov. 12, 2003.

FIELD OF THE INVENTION

The present invention relates to a processing device and display system, and in particular to a method and a system for incorporating hemodynamic and electrophysiological information into ventilation maneuvers.

BACKGROUND OF THE INVENTION

Hospitals routinely monitor physiological parameters of patients from first entry until final release. Originally, this was performed by one or more patient monitoring devices, such as a heart rate monitor, an EKG monitor, an SpO_2 monitor, and so forth. These physiological parameters were separately detected by separate pieces of equipment, possibly manufactured by respectively different manufacturers. The monitoring equipment included the connections to the patient necessary to measure the physiological parameter and a display device of the type necessary to display the physiological parameter in an appropriate manner. A healthcare worker, such as a nurse, visited the patient's location and looked at each separate system to accumulate the patient's vital signs.

Current systems have integrated measurement of some of the physiological parameters (e.g. EKG, SpO_2, etc.) into a single patient monitoring device. Such a device includes the patient connections necessary to measure the physiological parameters measurable by the device and a display device which can display the measured physiological parameters in an appropriate manner. Such patient monitors may be considered to be partitioned into two sections. A first, operational, section controls the reception of signals from the electrodes connected to the patient and performs the signal processing necessary to calculate the desired physiological parameters. A second, control, status and communication, section interacts with a user to receive control information and with the operational section to receive the physiological parameters, and displays status information and the values of the physiological parameters in an appropriate manner. Either or both of these sections may include a computer or processor to control the operation of that section. This approach has an economic advantage since the control, status and communication section is shared among the parameter monitoring functions.

Such patient monitors may also be connected to a central hospital computer system via a hospital network. In this manner, data representing patient physiological parameters may be transferred to the central hospital computer system for temporary or permanent storage in a storage device. Data received from the patient monitors may also be monitored by a person, such as a nurse, at the central location. The stored data may be retrieved and analyzed by other healthcare workers via the hospital network. Patient monitors in such a networked system include a terminal which is capable of being connected to and communicating with the hospital network. In such a patient monitor, the control, status and communication section controls the display of the physiological parameters, and also the connection to the hospital network and the exchange of the physiological parameters with other systems, such as other patient monitors and/or the central computer storage device, via the hospital network.

Such patient monitoring modules may also be portable. That is, they may operate while being transported with a patient who is being moved from one location to another in the hospital, for example, between a patient room and a therapy or operating room. A portable patient monitor consists of a base unit, and a portable unit which may be docked and undocked from the base unit. Base units may be placed at appropriate locations in the hospital. They are permanently connected to the hospital network and receive power from the power mains. The portable unit includes the necessary patient connections, connections for docking with base units, and a display screen. The portable unit also includes a processor which controls the operation of the portable unit The portable unit further includes a battery and an internal memory device.

While the portable unit of the patient monitor is docked, the batteries are recharged, and data representing physiological parameters are transmitted to the central hospital computer through the base unit via the hospital network. While the portable unit of the patient monitor is undocked, it runs on battery power. During transportation, the patient monitor continues to receive and display physiological parameters, and stores a record of those parameters in the internal memory device. If a base unit is available at the destination, the portable unit may be docked there. Communications is reestablished with the hospital central computer, and battery recharging commenced. At this time, data representing the previously stored parameters is retrieved from the internal memory device and transmitted to the storage device in the central hospital computer via the hospital network.

In such a patient monitor, the control, status and communication section controls display of the physiological parameters and communication of those parameters to the hospital network via the docking unit, and also detection of docking and undocking, control of power (either from the base unit when docked or the internal battery when undocked), storage of physiological parameter data in internal memory when the patient monitor is undocked, and transmission of stored physiological parameter data when the patient monitor is redocked.

Patient monitors have also been adapted to be used to transmit information to the hospital network from other modules. These modules may be patient monitoring modules measuring physiological parameters which are not measured by the patient monitor, or patient treatment modules reporting the status of treatments being provided to the patient. Such patient monitors include input terminals, or wireless input ports, to which these other monitoring modules are connected. Information from these modules is passed through the patient monitor to the hospital network through the base unit.

FIG. **1** is a block diagram of a hospital **100** operating in the manner described above. In FIG. **1**, four rooms in a hospital are illustrated: an operating room **102**, an intensive care unit (ICU) room **104**, an emergency room **106** and another critical care room **108**. The operating room **102**, the ICU room **104** and the emergency room **106** include a patient monitor device as described above. Each patient monitor includes a connection to a critical care area network **110**, either directly from the patient monitor or through a base unit (not shown). Each patient monitor also includes patient connections to electrodes attachable to the patient, not shown to simplify the figure. The patient monitors also receive data from other devices and forward that data to the critical care area network. In the operating room **102**, an anesthesia device and fluid

management device are coupled to the critical care area network **110** through the patient monitor; in the ICU room a ventilator device and fluid management device are coupled to the critical care area network **110** through the patient monitor; and in the emergency room **106** a ventilator device is coupled to the critical care area network **110** through the patient monitor. In the other critical care room **108** a ventilator device is coupled directly to the critical care area network **110**, either directly or through its own base unit.

The modules illustrated in FIG. **1** operate independently of each other, and each includes its own computer or processor controlling the module. This requires the presence of a base unit for each separate module. In an operating room, where many such modules may be in use concurrently, this requires space, and power. Further, each device may be docked in a base unit for that type of device. That is, a patient monitor device may be docked in a patient monitor base unit, a fluid monitoring device may be docked in a fluid monitoring device base unit, and so forth.

A patient monitor is passive in the sense that it monitors physiological parameters of the patient to which it is attached. However, other medical devices are active in the sense that their operation affects the patient in some manner. For example, the anesthesia device controls the administration of anesthesia to a patient, e.g. during an operation; the fluid management device controls the administration of fluids (blood, saline, and/or medication) to a patient; the ventilator device assists or controls breathing of a patient, e.g. during an operation, and so forth. The active devices also include a computer or processor which controls the operation of the device. These devices also may be connected to a hospital network through a base unit. This allows a central location to monitor and to control the active device. As with the patient monitoring device, an active device, such as a fluid monitoring device, may be portable in the sense that a control module, including a processor, may be undocked from a fixed unit. This control module continues to operate the device, at the last received control settings, e.g. while a patient is transported from one location to another. When at the new location, the control module may be docked in a fixed unit at the new location and control by a central computer resumed.

The existing processing and display systems, described above. used in patient monitoring and treatment have numerous limitations. Such existing processing systems employ different software for monitor computers, anesthesia computers, ventilation computers, and fluid management computers. Further, system devices are typically transported and connected to a particular corresponding type of medical device computer (e.g., a monitor device may be transported and connected to a corresponding monitor computer). Further, in existing systems, medical device processing devices and displays are typically able to view and control parameters and functions of other like devices, that is, a monitor processing device and display is limited to be able to view and control parameters and functions of another monitor processing device and display. In addition, existing systems typically derive patient parameters using specialized equipment and devices individually tailored to process a specific corresponding type of patient parameter. These devices require multiple individual electrical connections and fail to provide inter-device communication and central parameter processing capability.

Consequently to provide a desired therapy to a patient, the patient monitoring and/or treatment modules required to provide that therapy is assembled at the patient bedside. They are attached to the patient, and separately configured. Further, to provide the desired therapy may require changing the settings of one of the patient treatment devices based on readings derived from another device, are required. Because the different patient monitoring and/or treatment modules are from different sources and include different user interfaces, there is a significant risk of a mistake being made in the settings of one device based on the readings from another. In order to minimize such mistakes, detailed instructions are provided to the clinician for operating the patient monitoring and/or treatment devices required to provide the desired therapy, and the requirement for human interaction with the patient monitoring and/or treatment modules slows the process of providing the desired therapy.

A wide variety of lung recruitment maneuvers are desirable respiratory therapies in the event of acute restrictive lung failure. It can be therapeutically beneficial, especially at an early stage, to reventilate lung areas which have collapsed in the course of the illness by inflating them with an applied pressure or volume over an adequate period of time. Following such a maneuver, the lungs need to be stabilized with an adequate positive end expiratory airway pressure (PEEP). The PEEP required for this is identified by measures such as an expiratory low flow maneuver or a slow step-by-step reduction in PEEP until the first manifestation of a so-called derecruitment—that is, a disproportionately high decrease in volume relative to the reduced pressure.

Therapeutic limitations, both in recruitment maneuvers and in maneuvers to determine the ideal ventilation settings, are typically the high pressures exerted over a long period of time on the chest cavity which reduce the venous return flow to the right heart and thus the cardiac output and the arterial pressure. As a countermeasure, a patient may be provided with an additional volume of circulating blood, in an effort to maintain an appropriate cardiac output and provide an adequate degree of blood flow (i.e., perfusion) to important tissues. However, the additional volume of circulating blood may result in the negative effect of increasing the intrathoracal pressure in the patient's chest cavity. Furthermore, if the pressure is suddenly and drastically reduced, the blood volume suddenly flowing back out of the capacity vessels (i.e., veins) into the right heart may overstrain the heart, particularly in patients with a coronary heart condition. If there is an insufficiency of the left heart, excessive volume input can lead to lung edema. A system according to invention principles addresses these deficiencies and related problems.

BRIEF SUMMARY OF THE INVENTION

In accordance with principles of the present invention, a method and system for managing patient ventilator operation. A patient monitoring module receives data representing one or more hemodynamic parameters. A central processor, in response to the received data representing one or more hemodynamic parameters, provides one or more commands for adaptively altering ventilator operation. A patient treatment module provides signals for adaptively altering ventilator operation in response to the one or more commands from the central processor.

BRIEF DESCRIPTION OF THE DRAWING

In the drawings:

FIG. **1** is a block diagram of a prior art hospital system for monitoring patients and providing treatment to patients; and

FIG. **2** is a block diagram of a hospital system for monitoring patients and providing treatment to patients according to principles of the present invention;

FIG. **3** is a more detailed block diagram illustrating the interconnections of the central processor and the patient monitoring and treatment modules;

FIG. **4** is a more detailed block diagram of a central unit illustrated in FIG. **3**;

FIG. **5** is a diagram illustrating the relationship between different components of the software controlling the central unit;

FIG. **6** is a flow diagram illustrating steps performed by an embodiment according to invention principles.

DETAILED DESCRIPTION OF THE INVENTION

FIG. **2** is a block diagram of a hospital system **200** for monitoring and providing treatment to patients. In FIG. **2**, the same four rooms are illustrated as are illustrated in FIG. **1**, and those rooms contain the same medical equipment. The operating room **202** includes a patient monitoring module **210** for acquiring and processing signals derived from sensors (not shown) suitable for attachment to a patient. The operating room **202** also includes patient treatment modules: a fluid infusion (IV pump) control and management module **212** and an anesthesia module **214**. These modules (**210**, **212** and **214**) are coupled to a central processor **220** via a patient area network (PAN) **216**. The central processor **220** is coupled to a display generator **222** which is coupled to a display device **223**. The display generator **222** is also optionally coupled to a slave display device **224**, as illustrated in phantom. The ICU room **204** includes a monitor module, a fluid management patient treatment module and a ventilator module, coupled to a central processor via a PAN. The emergency room **206** includes a monitor module and a ventilator patient treatment module coupled to a central processor via a PAN. The other critical care room **208** includes a ventilator patient treatment module coupled to the central computer via a PAN **216**.

In operation, the PAN **216** may be implemented in any manner allowing a plurality of modules to intercommunicate. For example, the PAN **216** may be implemented as an Ethernet network, either wired or wireless (WLAN). If implemented as a wireless network, it may be implemented according to available standards, such as: (a) a WLAN 802.11b compatible standard, (b) 802.11a compatible standard, (c) 802.11g compatible standard, (d) Bluetooth 802.15 compatible standard, and/or (e) GSM/GPRS compatible standard communication network.

The patient monitoring module **210** corresponds to the operational portion of a prior art patient monitor described above. It receives signals from the electrodes and sensors attached to the patient, performs the signal processing required to calculate the physiological parameters, and provides that information to the central processor **220** via the PAN **216**. Similarly, the patient treatment modules, i.e. the fluid management module **212** and the anesthesia module **214**, correspond to the operational portion of the prior art treatment modules described above. The patient treatment modules **212**, **214** receive operational data from the central processor **220** via the PAN **216** and in response perform their treatment functions, e.g. monitoring fluids administered to the patient and supplying anesthesia to the patient, respectively. Concurrently, the patient treatment modules **212**, **214** send status data to the central processor **220** via the PAN **216**. The central processor **220** processes the signals received from the patient monitoring module **210** and the patient treatment modules **212** and **214**.

The central processor **220** interacts with the user to receive patient identifier information and treatment instructions and parameters. The central processor **220** configures the patient treatment modules **212**, **214** by sending patient identifier information, the treatment instructions and parameters to the patient treatment modules **212** and **214** via the PAN **216**.

The patient monitoring and/or treatment modules **210**, **212**, **214** may include a processor for receiving the configuration parameters from the central processor **220**, for controlling the operation of the module **210**, **212**, **214** and for sending status and patient physiological parameter information to the central processor **220** via the PAN **216**. The configuration parameters may include patient identifier information, set-up parameters, and/or data representing executable instructions for execution by the processor in the module **210**, **212**, **214** in processing data to be provided to the central processor **220**. The modules **210**, **212**, **214**, in turn, use the received configuration parameters, and executable instructions in supporting their operation, e.g. for processing data to be provided to the central processor **220**.

As described above, there may be more than one central processor **220** in remote locations in the hospital. If a module **210**, **212**, **214** is disconnected from one central processor **220**, then the patient identifier information, the set-up parameters and/or the executable instructions previously sent to it are used to control the operation of that module **210**, **212**, **214** while it is disconnected. If the disconnected module **210**, **212**, **214** is reconnected to a central processor **220**, possibly in a different location than the central processor **220** from which it is disconnected, then the reconnected module **210**, **212**, **214** sends data representing the patient identifier information, the operational characteristics of the module, and any patient physiological parameter data gathered while disconnected to the central processor **220** to which it is connected.

The central processor **220** also receives signals representing physiological parameters from the patient monitoring module **210** and possibly from the patient treatment modules **212**, **214**. These parameters may be relatively standard physiological parameter, such as EKG, heart rate, SpO_2, etc. The central processor **220** may also initiate generation of a new parameter based on signals derived using the patient monitoring module **210** and/or the patient treatment modules **212**, **214**. For example, the new parameter may be associated with (a) gas exchange, (b) skin color, (c) haemodynamics, (d) pain and/or (e) electro-physiology.

The central processor **220** conditions the display generator **222** to generate signals representing an image for displaying these physiological parameters in an appropriate manner, e.g. a waveform, a status phrase or a number. The display generator **222** is coupled to the display device **223** which displays this image. The display generator **222** may optionally send appropriate image representative signals to the slave display device **224**. The slave display device **224** may have a larger, higher resolution screen, or may simply be a display device at a location remote from the location of the central processor. The image generated by the display device **223**, under the control of the central processor **220** and display generator **222**, may also integrate the display of patient identification, treatment instructions and parameters and status from the patient treatment modules **212**, **214** in an appropriate manner. In this manner, information from users as well as patient monitoring modules **210** and patient treatment modules **212**, **214** may be integrated into one or more composite images displayed on display devices **223** and **224**, for example.

The central processor **220** may also communicate with the central processors of corresponding processing device and display systems in other locations in the hospital, such as those in the ICU room **204**, the emergency room **206** and the other critical care room **208** via the critical care area network **205**. The central processor **220** may optionally communicate

with a central hospital location via a hospital network **230**, illustrated in phantom in FIG. **2**. In this manner, patient physiological parameters and treatment instructions, parameters and status may be transmitted to a central location and stored in a central storage device **232**, also illustrated in phantom.

FIG. **2** illustrates a patient monitoring module **210**, and patient treatment modules for fluid management **212**, anesthesia control **214**, and ventilation control. However, one skilled in the art will understand that there are other monitoring and treatment devices which may include patient treatment modules for control and communication, such as: (a) an incubator, (b) a defibrillator, (c) a warming module, (d) a diagnostic imaging module, (e) a photo-therapy module, (f) a fluid input support module, (g) a fluid output support module, (h) a heart-lung support module, (i) a blood gas monitor, (j) a controllable implanted therapy module, (k) a controllable surgical table and weighing scale, and so forth. Modules for command and communication related to these and other patient treatment devices may be used as illustrated in FIG. **2**.

FIG. **3** is a more detailed block diagram illustrating the system illustrated in FIG. **2**. In FIG. **3**, those elements which are the same as illustrated in FIG. **2** are designated by the same reference number and are not discussed in detail below. FIG. **3** illustrates the system as it would be implemented in one of the rooms **202**, **204**, **206** or **208** of FIG. **2**. In FIG. **3**, the central processor **220** and the display generator **222** are comprised within a central unit **300**. The central unit **300** is a housing containing the circuitry and connectors necessary to interconnect the central processor **220** and the display generator **222** with: the patient monitoring and patient treatment modules **210**, **212**, **214**, **250** and **260**; the display devices **224**, **320** and **330**; and the multi-patient LAN **205** and hospital LAN **230**.

The central processor **220** is coupled to a communications and power hub **235**. The communications and power hub **235** comprises the patient area network (PAN) **216** and also a set **240** of module connectors coupled to the PAN **216**: e.g. a patient monitor connector **241**, a ventilator connector **243**, a fluid management hub connector **245**, an anesthesia delivery system connector **247** and a fluid (IV pump) management connector **249**. The connectors **240** permit the individual modules **210**, **212**, **214**, **250**, **260** to be plugged into and removed from the central unit **300** as required. In one embodiment, a user may activate a single mechanical release mechanism to remove a module **210**, **212**, **214**, **250**, **260** from the central unit **300** or reattach a module to the central unit **300**. The connectors **240** pass data signals between the modules **210**, **212**, **214**, **250**, **260** and the central processor **220** via the PAN **216**.

The communications and power hub **235** further comprises a power bus **234** for distributing power to the central unit **300**. The power bus **234** is further coupled to the PAN **216** for receiving commands from and returning status to the central processor **220**. The power bus **234** is also coupled to the connectors **240** (not shown to simplify the figure) to distribute power to the patient monitoring and/or treatment modules **210**, **212**, **214**, **250**, **260**. In this manner, the central processor **220** may manage the power-on and power-off status of the patient monitoring and treatment modules **210**, **212**, **214**, **250**, **260** in accordance with a set of predetermined rules maintained in the central processor **220**.

As described above, at least some of the attached modules **210**, **212**, **214**, **250**, **260** include circuitry, e.g. batteries, which permit them to continue to operate when disconnected from the central unit **300**. When docked, the central processor **220** conditions these modules **210**, **212**, **214**, **250**, **260** to transition from operating on battery power to operating on the power supplied by the power bus **234** and recharge their batteries. The internal power supply circuitry of these modules **210**, **212**, **214**, **250**, **260** may also supply power supply status information, e.g. current battery capacity, to the central processor **220** through the connectors **240** and PAN **216**. The central processor **220** may condition the display generator **222** to generate signals representing an image showing the battery charging condition of the patient monitoring and treatment modules **210**, **212**, **214**, **250**, **260** plugged into the central unit **300**. This image may be displayed on the display devices **321**, **331** and/or **225** in the main control panel **320**, slave control panel **330** and/or remote display device **224**, respectively.

As described above, the PAN **216** may be implemented as a wireless network. In such an embodiment, the central processor **220** may include a wireless communication interface to the PAN **216**. Such an interface enables bidirectional communication with the patient monitoring and treatment modules **210**, **212**, **214**, **250**, **260** when they are disconnected from the central unit **300**. This communications link enables the central processor **300** to maintain control of the patient monitoring and treatment modules **210**, **212**, **214**, **250**, **260** while they are disconnected from the central unit.

Individual patient monitoring and/or treatment modules **210**, **212**, **214**, **250**, **260** are coupled to corresponding ones of the connectors **240**. For example, a patient monitor module **210** may be plugged into the monitor connector **241**, a ventilator module **250** may be plugged into the ventilator connector **243**, and so forth. The central unit **300** may include connectors **241**, **243**, **245**, **247**, **249** which are specific to the type of patient monitoring or treatment module, **210**, **212**, **214**, **250**, **260**, expected to be plugged in. Alternatively, the modules **210**, **212**, **214**, **250**, **260** may be fabricated with the same type of connector and the connectors **240** may be the same type of matching connectors. In the former embodiment, a particular type of patient monitoring or treatment module **210**, **212**, **214**, **250**, **260** may be plugged into a connector **241**, **243**, **245**, **247**, **248** corresponding to that type of module. In the latter embodiment, any patient monitoring or treatment module **210**, **212**, **214**, **250**, **260** may be interchangeably plugged into any of the connectors **241**, **243**, **245**, **247**, **248**.

As described above, the patient monitor module **210**, plugged into the monitor connector **241**, connects to a plurality of electrodes and sensors which may be placed on a patient. A monitoring pod **211** is used to connect the patient-connected electrodes to the patient monitor module **210**. Similarly a ventilator module **250** may be plugged into the ventilator connector **243**. The ventilator module **250**, in turn, is coupled to a blower **254** and a humidifier **252**. A fluid management hub **260** is plugged into the fluid management hub connector **245**. Two fluid (IV pump) management modules **264** and **266** are plugged into the fluid management hub **267**. Each fluid (IV pump) management module, **264**, **266**, is connected to an IV pump (not shown). An anesthesia delivery module is plugged into an anesthesia delivery connector **247**. The anesthesia delivery module **214** is connected to a anesthesia delivery device (not shown). An individual IV pump **212** is coupled to an IV pump connector **249**. Similar to the other IV pump modules **264** and **266**, the fluid (IV pump) management module **212** is connected to an IV pump (not shown).

The central processor **220** is also coupled to the critical care area LAN **205**, which, as illustrated in FIG. **2**, is coupled to other central units **300** in processing device and display systems in other rooms. The central processor **220** may also be optionally coupled to a hospital LAN **230**. The critical care

LAN **205** requires real time bandwidth quality-of-service while the hospital LAN **230** requires standard office bandwidth quality-of-service. As described above, if connected to a hospital LAN **230**, the central processor **220** may exchange data with a central storage device **232**, or any other desired device (not shown) at a remote location in the hospital. Data may be sent from patient monitoring and/or treatment modules **210**, **212**, **214**, **250**, **260** to the central storage device **232** through the connectors **240** to the central processor **220** via the PAN **216** and from there to the central storage device **232** via the hospital LAN **230**. In addition, control data may be sent in the other direction from the central location to a patient monitoring or treatment module **210**, **212**, **214**, **250**, **260**.

It is further possible that a central processor **220** in a central unit **300** in a processing device and display system in one treatment room **202**, **204**, **206**, **208** may communicate with a second central processor **220** in a central unit **300** in a processing device and display system in a different treatment room **202**, **204**, **206**, **208** (FIG. **2**) via the critical care area LAN **205** or the hospital LAN **230**. In this manner, the central processor **220** in one treatment room may control the operation of the second central processor **220** in the second treatment room; may display patient related data received from the second central unit **300** in the different treatment room; and/or may send (a) a patient identifier identifying a particular patient and/or (b) medical information related to the particular patient to the second central processor **220** in the central unit **300** in the second treatment room **202**, **204**, **206**, **208**, which receives this information.

It is also possible for the central processor **220** to receive data from one or more of the patient monitoring and/or treatment modules **210**, **212**, **214**, **250**, **260**, process that data and send control data to one or more of the patient treatment modules **212**, **214**, **250**, **260** in response to the received data, in a manner to be described in more detail below.

The display generator **222** is coupled to a main control panel **320**. The main control panel **320** includes a display device **321**, a keyboard **322** and a pointing device in the form of a mouse **324**. Other input/output devices (not shown) may be fabricated on the main control panel **320**, such as: buttons, switches, dials, or touch screens; lights, LCDs, or LEDs; buzzers, bells or other sound making devices, etc. These input/output devices receive signals from and supply signals to the central processor **220**, either through the display generator **222**, or through separate signal paths, not shown to simplify the figure. The main control panel **320** may be fabricated as a part of the central unit **300**, or may be fabricated as a separate unit. The display generator **222** is optionally coupled to a slave control panel **330**, which substantially duplicates the functionality of the main control panel **320**, but is located remote from the central unit **300**. The display generator **222** is also optionally coupled to a slave display device **224**. The slave display device **224** includes a display device **225**, but does not include any of the other input/output devices included in the main control panel **320** and slave control panel **330**.

In operation, the central unit **300** and main control panel **320** provide control and display functions for the patient monitoring and/or treatment modules **210**, **212**, **214**, **250**, **260** which are plugged into the common unit **300**. A user may manipulate the input devices coupled to the main control panel **320**, or slave control panel **330** if available, e.g. the keyboard **322**, mouse **324** or other input devices described above. The resulting signals are received by the central processor **220**. In response, the central processor **220** sends control signals via the PAN **216** to the patient monitoring or treatment modules **210**, **212**, **214**, **250**, **260** which are currently plugged into the central unit **300**.

Concurrently, the central processor **220** receives data signals from the patient monitoring and/or treatment modules **210**, **212**, **214**, **250**, **260**, as described above, and conditions the display generator **222** to produce a signal representing an image for displaying the data from the patient monitoring and/or treatment modules **210**, **212**, **214**, **250**, **260**, in an appropriate manner. For example, if a patient monitor **210** having the capability of performing an EKG on a patient is plugged into the central unit **300**, EKG lead data from the patient monitor **210** is supplied to the central processor **220** through the monitor connector **241** via the PAN **216**. The central processor **220**, in turn, conditions the display generator **222** to produce signals representing an image of the EKG lead signal waveforms. These image representative signals are supplied to the display device **321** in the main control panel **320**, which displays the image of the waveforms of the EKG lead signals. An image representing the heart rate of the patient, derived from the EKG lead signals, may also be similarly displayed in numeric form. Images representing other physiological parameters measured by the patient monitor **210**, e.g. blood pressure, temperature, SpO_2, etc. may also be displayed, in an appropriate form, on the display device **321** of the main control panel **320** in a similar manner. The image data may also be displayed on the display device **331** of the slave control panel **330** and on the display device **225** of the slave display **224**, if they are available.

In a similar manner, images representing data received from the patient treatment modules, **212**, **214**, **250**, **260**, may be displayed on the display devices **321**, **331**, **225** in an appropriate form. Such data may represent, for example, present settings for the respective treatment modules, such as specified drip rates for IV pumps attached to fluid management modules **212**, **264**, **266**. This data may be represented by images of appropriate form. Such data may also represent physiological parameters which may be measured by the patient treatment devices **212**, **214**, **250**, **260**. For example, respiration loops may be displayed in graphical form based on data received from the ventilator module **250**, or drip rates for attached IV pumps may be displayed in numerical form based on data received from the fluid management hub **260**.

A user may select which physiological parameters to display on the display device **321** and may arrange the location on the display device **321** of the images displaying the selected physiological parameters. In addition, the user may select different physiological parameters to display on the display device **321** in the main control panel **320** than on the display device **331** in the slave control panel **330** and/or on the display device **225** in the slave display **224**. Further, the slave display device **224** may have a display device **225** which is larger and/or higher resolution than those in the main control panel **320** and the slave control panel **330**, so that the images may be more easily seen, and/or may be displayed at an increased resolution.

The central processor **220** may also receive data from the power bus **234** via the PAN **216** representing the state of the power supplies in the patient monitoring and treatment modules **210**, **212**, **214**, **250**, **260**. The central processor **220** may, for example, condition the display generator **222** to generate a signal representing an image representing the current charge condition of the respective batteries in the patient monitoring and treatment modules **210**, **212**, **214**, **250**, **260** plugged into the central unit **300**, either separately or in composite, based on data received from the power bus **234**. Further, the patient monitoring and/or treatment modules **210**, **212**, **214**, **250**, **260** may provide data to the central processor **220** indicating an

error condition in the module. The central processor **220** may condition the display generator **222** to generate a signal representing an image showing the user the error condition of that module.

The central processor **220** may also produce signals for controlling the operation of the other output devices on the main and slave control panel **320**, **330**, described above. For example, the central processor **220** may analyze the physiological parameters derived from signals received from the patient monitoring and/or treatment modules **210**, **212**, **214**, **250**, **260** to determine if any limits have been exceeded. This may entail separately calculating and verifying each physiological parameter response determined from a patient monitoring and/or treatment module, and comparing it to a predetermined parameter range to determine if it exceeds a limit, or analyzing more than one physiological parameter to determine if a function of those physiological parameters exceeds a limit. If a limit has been exceeded, then the central processor **220** may condition the output devices on the main and slave control panel **320**, **330** to provide an alarm. For example, the central processor **220** may generate a signal which activates a light, a buzzer, a bell and/or other such device on the main control panel **320**, and/or the slave control panel **330**, if available, to produce a visible or an audible alarm. The central computer **220** may also send a signal over the critical care area LAN **205** and/or the hospital LAN **230** indicating that a limit has been exceeded. A similar alarm may be generated at the remote location in response to the receipt of this signal.

FIG. **4** is a more detailed block diagram of a central unit **300** illustrated in FIG. **3**. In FIG. **4**, those elements which are the same as those illustrated in FIG. **3** are designated by the same reference numbers and are not described in detail below. In FIG. **4**, the central unit **300** is implemented on a computer system similar to typical personal computers. In such systems, a central processing unit (CPU) **402** controls the operation of the remainder of the system. The other elements illustrated in the central unit **300** are coupled to the CPU **402**, though the connections are not shown to simplify the figure.

In FIG. **4**, a power supply **450** provides power to the central unit **300**. The power supply **450** may be coupled to the power mains. The power supply **450** may also include batteries to provide power to the central unit **300**. The batteries may operate in an emergency backup mode, in which if a power failure occurs at the power mains the battery is switched to supply power to the central unit. Alternatively, batteries may provide main power to the central unit, and the power mains used to maintain the battery at full charge, or to recharge the battery after a power failure. One skilled in the art will understand that other arrangements for supplying power to the central unit **300** are possible.

A first Ethernet adapter **404** couples the CPU **402** to the patient area network (PAN) **216**, which in turn is interconnected with patient monitoring and/or treatment modules **210**, **212**, **214**, **250**, **260**. A second Ethernet adapter **406** couples the CPU **402** to the critical care area LAN **205**. A third Ethernet adapter **432** couples the CPU **402** to the hospital LAN **230** which in turn is interconnected with the central storage device **232**.

The display generator **222** couples the CPU **402** to the display devices **321**, **331** and **225** in the main control panel **320**, the slave control panel **330** and the slave display **224**, respectively. A set of panel I/O ports **410** couple the CPU **402** to the panel I/O devices, described above, on the main control panel **320** and the slave control panel **330**. As previously described, such I/O devices may include rotary switches, touch panels, pushbutton keys, lights, and so forth.

A watchdog circuit **430** checks the proper operation of the CPU **402** and produces a signal indicating a fault condition if the CPU **402** is not operating properly. The watchdog circuit **430** may check for proper operation of the CPU **402** using any of a variety of methods. For example, the watchdog circuit **430** may send a challenge signal at regular intervals to the CPU **402**. If the CPU **402** is operating properly, it receives and recognizes the challenge signal, and provides a reply signal back to the watchdog circuit **430**. If the watchdog circuit **430** does not receive the reply signal back from the CPU **402** within a specified time of issuing the challenge signal, then it detects a fault in the CPU **402**, and produces the fault condition signal. The watchdog circuit **430** may also attempt to restart operation, i.e. reboot of the CPU **402**, upon detecting a fault in the operation of the CPU **402**.

The remainder of the elements illustrated in the central unit **300** are typically included in personal computers. A keyboard/mouse interface **408**, typically using a PS/2 or USB standard, couples the keyboard **332** and mouse **324** to the CPU **402**. A sound card **412** responds to instructions from the CPU **402** to generate sound representative signals, which may be coupled to speakers (not shown) to reproduce sound. A read-write memory unit (RAM) **414** provides local storage for programs controlling the CPU **402** and for data used and/or created by the CPU **402**. A serial port **416** exchanges serial binary data signals with external peripherals e.g. using the RS232 standard. A USB port **418** similarly exchanges serial binary data signals with external peripherals using the USB standard. A DVD/CD player **420** allows the CPU **402** to access data on DVDs and/or CDs. It is also possible to write data onto DVDs and/or CDs. An expansion card port **422** allows the CPU to exchange data with portable devices, such as a Personal Computer Memory Card International Association (PCMCIA) card, Compact Flash (CF), Secure Digital (SD), and so forth. A real time clock (RTC) **424** with its associated battery **425**, maintains and provides current time and date to the CPU **402**. An integrated drive electronics (IDE) bus **426**, into which conforming cards may be plugged, allow such cards to exchange information with the CPU **402**. Similarly, a peripheral component interconnect (PCI) bus, into which conforming cards may be plugged, allow such cards to exchange information with the CPU **402**. Cards plugged into either the IDE bus **426** or the PCI bus **428** may be coupled to peripheral devices, both internal and external to the central unit **300**, and permit the CPU **402** to exchange data with the peripheral devices.

In operation, the CPU **402** interacts with the peripheral devices connected to it under control of software. Because the central unit **300** is designed and implemented similarly to a typical personal computer, it may be controlled using software typically executed on a personal computer, augmented by executable applications for performing specialized tasks related to monitoring and providing treatment to patients.

FIG. **5** illustrates the relationship and interaction among different components of the central unit **300**, including both the hardware platform **504** (as illustrated in FIG. **3** and FIG. **4**) and a system executable application **500**. As described above, an executable application is any set of executable instructions, code or machine readable instructions for controlling the operation of a programmable processor or conditioning a processor to implement predetermined functions, such as those of an operating system, a context acquisition system or other information processing system, for example, in response to user command or input. It may include software, firmware and hardware, as appropriate, and one skilled in the art will understand how to partition the executable application into software, firmware and hardware, and the design criteria

and tradeoffs involved. Because, as described above, the components illustrated in FIG. **5** are implemented on a hardware system based on available PC systems, the executable application described in FIG. **5** is implemented in software, and will be termed system software **500** below.

A user interface (UI), as used herein, comprises one or more display images, generated by a display processor and enabling user interaction with a processor or other device and associated data acquisition and processing functions. The UI also includes an executable procedure or executable application. The executable procedure or executable application conditions the display processor to generate signals representing the UI display images. These signals are supplied to a display device which displays the image for viewing by the user. The executable procedure or executable application further receives signals from user input devices, such as a keyboard, mouse, light pen, touch screen or any other means allowing a user to provide data to a processor. The processor, under control of an executable procedure or executable application manipulates the UI display images in response to the signals received from the input devices. In this way, the user interacts with the display image using the input devices, enabling user interaction with the processor or other device. The functions and process steps herein may be performed automatically or wholly or partially in response to user command. A document or record comprises a compilation of data in electronic or paper form.

Each element in FIG. **5** is represented by a rectangle. In general, elements, and the functions they provide, at lower levels of FIG. **5** may be accessed by elements at higher levels. At the bottom of FIG. **5** is the hardware platform **504**. The hardware platform **504** provides the hardware functions, described in more detail above, such as: providing control signals to, and receiving status and patient physiological parameter information from, patient monitoring and/or treatment devices **210**, **212**, **214**, **250**, **260**; exchanging data over the critical care area LAN **205** and hospital LAN **230**; providing image representative signals to display devices **222**, **225**, **321**, **331** (FIG. **3**), exchanging signals with panel I/O devices **410** (FIG. **4**), and so forth. The hardware platform **504** is not part of the system software **500** illustrated by the remainder of FIG. **5**.

The system software **500** illustrated in FIG. **5** includes a software framework **502** providing particular functions. The software framework **502** provides the software infrastructure for support of point of care based medical modules, such as the modules **210**, **212**, **214**, **250**, **260** (FIG. **2**, FIG. **3**, FIG. **4**). As used herein, the point of care (POC) is the area, in the vicinity of the patient, in which medical treatment is provided to a patient. The software illustrated in FIG. **5** may be embodied in PC based products. Table 1 (below), describes in detail the functions provided by the respective software components illustrated in FIG. **5**.

The software framework **502** includes a hardware dependent operating system **506**, which in FIG. **5** is an embedded windows operating system (OS) **506**. For example, an embedded version of Windows XP (by Microsoft Corp) OS **506** may be included in the software framework **502**. The OS **506** interacts with the hardware **504**, which may be different from product to product, or may change or be updated over time. The OS **506** also provides a set of application program interfaces (APIs) which are sets of common software interfaces which may be used by the remainder of the software and which remain unchanged despite differences in the hardware **504**. The remainder of the software illustrated in FIG. **5** is related to providing the functions required by the modules which may be controlled by the central unit **300**.

The software framework **502** further includes a set of common platform components **508** (see Table 1 (below)). These components provide monitoring and executive functions for the central unit **300**. Specifically, a watchdog function, a resource monitor, and a monitor for critical components are provided by the common platform components **508**. In addition, the common platform components **508** provide security, lifetime management, diagnostics, real time infrastructure and event management, safety and availability management, and user set up configuration support for the central unit **300**.

The software framework **502** also provides common communications component **510** (see Table 1 (below)). More specifically, the common communications component provides access to the PAN **216**, the critical care area network **205** and any other networks to which the central unit **300** may be coupled, such as the hospital network **230** (FIG. **3**). The common communications component **510** also provides peripheral support, e.g. communications with any other auxiliary device via the serial port, **416**, the USB port **418**, the expansion card port **422** and/or any other device which may be coupled to the central unit **300**, for example, via boards mounted in the IDE bus **426** or PCI bus **428**.

The software framework **502** also provides a common human interface component **512** (see Table 1 (below)). The common human interface component **512** provides functions for displaying graphical user interfaces (GUIs) on display devices **225**, **321**, **331** (FIG. **3**, FIG. **4**) and for coordinating the user inputs received from the input devices, such as keyboard **322** and mouse **324**, with the displayed GUI. This enables a user to control the configuration and operation of the system and to receive status and data representing patient physiological parameters from the system. These functions also provide parameter signal group support, deployment support, and user help.

These functions also include those GUI functions which are specific to a patient monitoring and treatment module, for example, support for the display of waveforms, such as EKG waveforms or respirator loops, maintenance of trends, and generation of reports. These GUI functions also include the ability for a user to arrange on the screen of the display device the images representing the physiological parameters of the patient. That is, to be able to move those images around on the screen, to resize them, to remove an image displaying a physiological parameter and/or to insert an image displaying a different physiological parameter. The common human interface **512** further supports maintenance of patient data and status, and the database containing these and/or other data items. The common human interface **512** component further provides alarm support and processing, including providing functions for generating an audible and/or visible alarm at the central unit **300** (FIG. **3**, FIG. **4**), and for transmitting alarm information to other locations, via the PAN **216**, the critical care area network **205** and/or the hospital network **230**. The common human interface component **512** also provides more standard GUI support for other software applications (described in more detail below), which may not be related directly to medical support.

The remainder of the components in the system software are application programs **520**. An application program is software which uses functions provided by the software framework **502**, described above, to support clinical domains and/or to provide clinical functions at the point of care. As used herein, a clinical domain is an area of a patient monitoring and/or treatment process. For example, patient monitoring is a clinical domain; patient ventilation is another clinical

domain; anesthesia and fluid administration are others, and so forth. The system software **500** includes several types of application programs **520**.

The application programs **520** include a set of common point of care (POC) applications **522** (CPOC) which are common to the clinical domains (see Table 1 (below)). The functions provided by the CPOC **522** are application-related but generic and not specific to any particular domain. That is, the central processor **402** in the central unit **300** executes at least a portion of the common code in the CPOC application **522** to support the operation of two or more of the patient monitoring and/or treatment modules **210**, **212**, **214**, **250**, **260**.

For example, the CPOC application **522** may provide a home screen from which other functions may be selected and configured. Functions for configuring and controlling the central unit **300** itself may be selected from the home screen, including: software option handling; application selection and configuration; remote control, both wired and wireless, from e.g. slave control units (FIG. **4**: **330**) or other central units via the critical care area network **205** and/or the hospital area network **230** (FIG. **2**); battery management; and so forth. In addition, functions related to patients may be selected from the home screen, including patient category, configuration, context, setup and demographic entry, editing, and transfer. The CPOC application **522** may also provide functions related to monitoring and/or treating patients, including: real-time processing of measurements, waveform display; alarm behavior, display and control; measurement setup and priority, events, trends, strip recordings; loop display; flow meter display; alarm limits and history, and so forth.

One skilled in the art will recognize that point of care (POC) patient monitoring and/or treatment modules, e.g. **210**, **212**, **214**, **250**, **260** (FIG. **3** and FIG. **4**), are typically associated with a specific clinical domain. That is, the monitoring module **210** is associated with the patient monitoring domain; the anesthesia module **214** is associated with the anesthesia domain, and so forth. Specific POC applications (SPOC), of which three **523**, **524**, **526** are shown to simplify the figure, respectively correspond to POC modules for specific domain areas. The respective SPOC applications **523**, **524**, **526** interact with associated ones of the modules **210**, **212**, **214**, **250**, **260**. For example, in FIG. **5**, SPOC **523** may be associated with one type of POC module, e.g. anesthesia module **214**; SPOC **524** may be associated with a different type of POC module, e.g. fluid management module **212**; and SPOC **526** may be associated with another POC module, e.g. patient monitoring module **210**.

Typically, SPOC applications **523**, **524**, **526** have a presentation function e.g. **523**A, a control and management function e.g. **523**B, a data server function e.g. **523**C, and a pluggable front-end (FE) module interface function e.g. **523**D. As used herein, the term pluggable front end module refers to a medical monitoring and/or treatment module, such as modules **210**, **212**, **214**, **250**, **260** (FIG. **2**, FIG. **3** and FIG. **4**), which may be connected to and disconnected from the central unit **300** during operation. The FE module interface function e.g. **523**D, bidirectionally communicates with patient monitoring and treatment modules **210**, **212**, **214**, **250**, **260**. These communications include control and status information and physiological parameter representative data. The data server function e.g. **523**C makes the control status and physiological data available to other applications. The presentation function e.g. **523**A makes the control, status and physiological data available to be displayed on the display devices **225**, **321**, **331** (FIG. **3**). The control and management function e.g. **523**B controls the operation of the SPOC and the FE module.

More specifically, the SPOC application **526**, which is associated with a patient monitoring module **210**, provides the specific functions required to control and interact with the monitoring module **210**. As described in more detail in Table 1 (below), the monitoring SPOC **526** provides module management, control and report functions, such as: monitor setup; export protocol management; nurse call; and setting display modes, including bedside and surgical display modes. The monitoring SPOC **526** also provides physiological parameter monitoring functions, such as: EEG, SpO_2, respiratory mechanics, invasive and non-invasive blood pressure, body temperature, transcutaneous blood gases, and so forth.

The SPOC application **523**, which is associated with the anesthesia module **214**, provides the specific functions required to interact with the anesthesia module **214**. As described in more detail in Table 1 (below), the anesthesia SPOC **523** provides module management, control and report functions such as: warm up; carrier gas selection, and so forth. The anesthesia SPOC **523** also provides anesthesia control and monitoring functions, such as anesthetic gas control, including N_2O, Xenon, etc.; consumption monitoring, and anesthetic gases supply, and so forth.

The SPOC application **524**, which is associated with the fluid management module **212**, provides the specific functions required to interact with the fluid management module **212**. As described in more detail in Table 1 (below), the fluid management SPOC **524** provides functions supporting different fluid managements modes, including: total controlled infusion (TCI), total intravenous anesthesia (TIVA), and patient controlled analgesia (PCA). As described above, other medical monitoring and/or treatment modules **210**, **212**, **214**, **250**, **260**, corresponding to other medical domains, are associated with SPOC applications which control and manage them. Details for these SPOCs are described in detail in Table 1 (below).

The application programs **520** further include cross domain POC applications (CDPOC), one of which **528** is shown in FIG. **5** to simplify the figure. CDPOC applications provide advanced integrated clinical information. This information may be derived from cooperative operation of two or more selected SPOC applications **523**, **524**, **526** controlling associated medical monitoring and/or treatment modules **210**, **212**, **214**, **250**, **260** in respectively different clinical domains such as monitoring, ventilation, anesthesia and/or fluid management. CDPOC applications coordinate the operation of the selected medical monitoring and/or treatment modules **210**, **212**, **214**, **250**, **260**, and integrate data received from them, as described in more detail below. One skilled in the art will understand that other CDPOC applications may be included in the application programs **520** which coordinate different SPOC applications; that more than two SPOC applications may be coordinated by a CDPOC application, and that an SPOC application may be associated with more than one CDPOC application.

Referring specifically to FIG. **5**, the CDPOC application **528** coordinates the operation of the fluid management SPOC **524** and the monitoring SPOC **526**. The fluid management SPOC **524** controls the operation of a fluid management treatment module **212** which may be administering a medication to affect a particular patient physiological parameter, such as blood pressure. The monitoring SPOC **526** controls the operation of the patient monitoring module **210** to monitor the patient blood pressure, among other things. The CDPOC application **528** monitors the patient blood pressure, as reported by the monitoring SPOC application **526** and controls the fluid management SPOC application **524** to con-

tinually adjust the administration of the blood pressure medication to maintain the patient blood pressure within limits specified by the physician.

The application programs **520** may further include imaging applications **530**, as described in more detail in Table 1 (below). These applications condition the various display devices, **225**, **321**, **331** (FIG. **3**) to display designated images in 2D and 3D modes. These imaging applications **530** further provide user control of panning and zooming, and for 3D images setting a point of view. The imaging applications **520** may also be used to produce: a virtual film sheet for e.g. x-rays, CAT scans, or any other group of related images; a patient scanner; a viewer for DICOM (Digital Imaging and Communications in Medicine) images retrieved via a query/retrieve operation, and so forth.

The application programs **520** may further include information technology (IT) applications **532**, as described in more detail in Table 1 (below). Such applications may include e.g. a chart assistant program, a remote viewing program, and other programs for exchanging and analyzing information. Other third party applications **534** may also be included in the application programs **520**. As used herein, third party applications **534** may provide clinical functions which may provide a benefit at the point of care, and may be developed outside and independently of the architecture developed for the central unit **300** to interact with the medical monitoring and/or treatment modules **210**, **212**, **214**, **250**, **260**. For example, medical image and report distribution, appointment scheduling, client records management, copayment tracking and billing, medical charting, insurance submission and billing, scheduling, and so forth are functions which may be provided by third party application programs **534**.

A Semantical Product Application (SPA) **536** provides coordination for the application programs **520** included in the system software. The SPA **536** covers the target domain or domains of the system, as configured with selected medical monitoring and/or treatment modules **210**, **212**, **214**, **250**, **260**. The SPA **536** uses, deploys and combines other application programs **520**. More specifically, the SPA **536** includes SPOC **523**, **524**, **526** configuration; CPOC **522** configuration; and CDPOC **528** configuration functions, and so forth. The SPA **536** also provides version management for the system.

The central units **300** in the respective critical areas and/or the hospital employ substantially the same type of CPU **402** and are implemented to support the operation of the different types of patient monitoring and/or treatment modules **210**, **212**, **214**, **250**, **260**. In addition, the central processor **220** in the respective central units **300** in the critical care area and/or the hospital employ substantially the same system software **500**, described above, supporting the operation of the patient monitoring and/or treatment modules **210**, **212**, **214**, **250**, **260**.

The hardware and software architecture described above and illustrated in FIG. **2**, FIG. **3**, FIG. **4** and FIG. **5** allows implementers to develop different products which address a desired medical domain or domains. As used herein, a product addresses the desired domains using the hardware and software architecture to provide a well defined set of applications for the target domains. That is a fabricator may produce a monitoring product by including a monitoring SPOC (e.g. **526**) and a patient monitoring module (e.g. **210**). Alternatively, further capability may be included, such as including a ventilation SPOC (not shown) and a ventilation patient treatment module (also not shown), a fluid management SPOC (e.g. **524**) and a fluid management patient treatment module (e.g. **212**), and an anesthesia SPOC (e.g. **523**) and an anesthesia patient treatment module (e.g. **214**). A CDPOC (e.g. **528**) application may be added to coordinate the operation of two or more SPOC applications.

More specifically, a fabricator may implement a product such as a transportable breathing support equipment system. Such a device is illustrated in FIG. **2** in room **208**. This system includes a central unit **300** (FIG. **3**) (not shown) which incorporates a central processor **208**B and docking connectors **240**. A ventilator module **208**A is coupled to the central processor **208**B and a display device **208**C via a PAN **208**D. The ventilator module **208**A controls a ventilator device (not shown) The ventilator device regulates the flow of breathable gas from a source (not shown) to the lungs of the patient. The ventilator module **208**A includes at least one battery which powers the module **208**A and the ventilator device itself during transportation. The docking connectors **240** allow other modules, such as a patient monitoring module **210**, an anesthesia module **214** and/or a fluid management module **212**, to be connected to the breathing support equipment system if desired. The system software **500** (FIG. **5**) detects the presence of these modules and automatically loads the SPOC applications required to control the newly added modules, **210**, **212**, **214**, **250**, **260**. The transportable breathing support equipment system may comprise a manually pushed, or power driven cart or trolley conveying the equipment.

Other products such as an emergency room product as illustrated in room **206** (FIG. **2**) and including a patient monitoring and ventilator module, or an ICU room product as illustrated in room **204** with a patient monitoring, ventilator and fluid management module, both with capabilities of adding further modules as required, may be implemented in a similar manner.

As described above, a CDPOC application **528** can advantageously coordinate the operation of two or more SPOC applications **523**, **524**, **526**, which in turn control the operation of associated patient monitoring and/or treatment modules **210**, **212**, **214**, **250**, **260**. This coordination enables the central processor **220** (FIG. **2**) to support monitoring operation of a patient treatment module **212**, **214**, **250**, **260** by (a) deriving data, based on combinations of parameters derived from the patient monitoring module **210** and a patient treatment modules **212**, **214**, **250**, **260**, for presentation to a user, and/or (b) prompting a user with suggested patient treatment module **212**, **214**, **250**, **260** configuration settings.

The central processor **220** may also verify the safety of the treatment by receiving data from the patient monitoring and/or treatment modules **210**, **212**, **214**, **250**, **260** and using said received data to determine whether settings of the treatment delivery devices attached to the patient treatment modules **212**, **214**, **250**, **260** are compatible with the desired treatment to be delivered to a patient. That is, the central processor **220** may verify the safety of a desired treatment by comparing patient physiological parameters received following initiation of delivery of a treatment, or following a change in the treatment induced by a corresponding change in the settings of a patient treatment module **212**, **214**, **250**, **260**, with predetermined physiological parameter value response ranges. In response to a determination that the settings of a patient treatment module **212**, **214**, **250**, **260** are incompatible with a desired treatment the central processor **220** may (a) automatically alter the settings and/or (b) initiate generation of an alert message to a user warning of the incompatibility.

This coordination among different patient monitoring and/or treatment modules **210**, **212**, **214**, **250**, **260** allows patient medical tests to be performed, and physiological parameters to be determined, by such a system, without requiring the use of more expensive, or more invasive testing methods. A single configured system as illustrated in FIG. **4** and FIG. **5**, for

example, advantageously automatically performs multiple different tests as described as follows. The tests in some instances may involve manual interaction. One skilled in the art will understand which patient monitoring and/or treatment modules to include in the system, how to coordinate the operation of these modules, and how to analyze the data from those modules to perform the desired medical tests.

A general form of such patient medical tests involves providing a predetermined physiological stimulus to a patient, monitoring the patient physiological parameters after the stimulus, and verifying an acceptable response. For example, the physiological stimulus may be (a) a medication, (b) a gas administered to said patient, (c) an electrical stimulus, (d) a physical or mechanical stimulus, (e) an application of heat or cold, (f) an acoustic stimulus, (g) a light stimulus and/or (h) a radiation stimulus. The patient physiological parameters monitored may be (a) BP, (b) HR, (c) RR, (d) SpO_2, (e) O_2, (f) CO_2, (g) NBP, (h) EEG and/or (i) blood gas parameters.

In the system described above, the central processor **220** (FIG. **4**) may initiate a stimulus by conditioning a patient treatment module **212**, **250**, **260** to temporarily change its operational setting, and using the patient monitoring module **210** to monitor subsequent physiological parameters to verify an acceptable response.

A more specific example of a medical test is a respiratory systolic variation test (RSVT), which may be performed by such a system. This test determines the blood filling conditions in the left atrium. It enables a physician to manage fluid input and output of a patient, and lung recruitment efforts (hypovolemea is often the reason for a patient not tolerating pressure-controlled inverse ratio ventilation (PCIRV)). The result of this test is a patient physiological parameter which may be displayed on the display devices **225**, **321**, **331** (FIG. **3**). Use of the system described above to provide the RSVT test is more accurate and less invasive than the use of a single use PA catheter, which at the present time costs around $100.

A Gedeon non-invasive cardiac output test (NICO) may also be performed by the system described above. This test estimates output of the left ventricle and effective gas exchange area of the lungs (i.e. the effective lung volume (ELV). It enables a physician to titrate the positive end-expiratory pressure (PEEP) for optimal CO and ELV after initiating mechanical ventilation. As used herein, the term "titrate" refers to the adjustment of a patient treatment parameter (such as the PEEP pressure) such that a desired patient physiological parameter is achieved (that is, optimal CO and ELV). The titration may be performed manually by the physician in response to the results of the test, or may be performed automatically under the control of a CDPOC (not shown) programmed to perform the test and titrate the PEEP parameter. The results of this test may be displayed on the display devices **225**, **321**, **331** (FIG. **3**). This test also aids a physician in starting or monitoring inotropic (i.e. cardiac output enhancing) drug therapy. Use of the system described above to perform the NICO test is less invasive than the conventional method and more accurate than other NICO methods.

A lung mechanics calculation test (LMC) may also be performed by the system described above. This test permits the modeling of a patient respiratory system in terms of elastic and resistive forces. More specifically, this test may determine inflection points in the respiratory cycle, i.e. points of alveolar collapse (atelectasis) during expiration and hyperinflation during inspiration. This test may also calculate physiological dead space, i.e. air which is inhaled by the body in breathing, but which does not partake in gas exchange. The results of the former test may be numerical or a graphic display, and the results of the latter test may be a numerical display, either or both of which may be displayed on the display devices **225**, **321**, **331** (FIG. **3**). The physician may use the results of this test to titrate the settings after initiating mechanical ventilation, or a CDPOC may be programmed to titrate the settings automatically. The LMC test has been tested and widely published. It is considered state-of-the-art at this time for lung mechanics. The NICO test requirements, described above, may be combined with this test.

A stress index test (SI) may also be performed by the system described above. This test quantifies the stress on the lungs induced by mechanical ventilation. More specifically this test detects and measures the effect of cyclic stretch, i.e. recruitment of alveola at the extreme end of inspiration and collapse at the extreme end of expiration. The results of this test may be numeric or graphical and may be displayed on the display devices **225**, **321**, **331** (FIG. **3**). A physician may use the results of this test to titrate ventilator settings, such as PEEP and tidal volume (V_T) to reduce stress on the lungs during ventilation, or a CDPOC may be programmed to titrate the settings automatically. The results of this test may also be used to predict the probability of success of a lung recruitment attempt. Ventilator settings made according to the SI test have been proven to reduce inflammatory markers in lung tissue.

An automatic lung parameter estimator test (ALPE) may also be performed by the system described above. This test assists a physician in quantifying the amount of pulmonary shunt and the distribution of pulmonary circulation (e.g. ventilation-perfusion ratio (V/Q) scatter). This test may also detect and quantify cardiac congestion, i.e. congestive heart failure (CHF). The results of this test may be numeric or graphical and may be displayed on the display devices **225**, **321**, **331** (FIG. **3**). A physician may use the results of this test to determine the use of diuretics and inotropic drugs to manage CHF. This test provides a comprehensive model of hemodynamic status and blood gasses non-invasively. This may be useful to a physician in the detection and management of CHF, which is a widespread disease, especially prevalent among respiratory patients.

Diaphragm electromyographically (EMG) controlled ventilation may also be advantageously performed by the system described above. In this ventilation mode the electrical signal related to the diaphragm muscle contraction is detected using electrodes on an oesphageal catheter. Because contraction of the diaphragm muscles occurs when a patient begins to take a breath, the EMG signal may be used to trigger the ventilator to begin a respiration cycle. Thus, this ventilation mode permits the patient's brain to advantageously control respiratory support. This mode may be selected by a user selection via the interaction of the GUI and user input devices such as the keyboard **322** and mouse **324**, or by panel I/O devices on the main control panel **320** and/or slave control panel **330** (FIG. **3**, FIG. **4**). Using EMG signals to trigger respiration permits ventilation to be more closely matched to the patient. This enables support of spontaneous breathing for a wider range of patients. This, in turn, makes mask ventilation more feasible, reducing complications associated with intubation, such as nosocomial pneumonia. These electrical signals may also provide ECG signals to measure the posterior of the heart and potentially detect atrial arrhythmias. The results of an ECG using EMG signals may be displayed on the display devices **225**, **321**, **331** in graphical form. An alarm may also be sent if an arrhythmia is detected. Detection of cardiac ischemia and atrial arrhythmias permits earlier intervention.

Some patients have responded successfully in certain therapy phases to the maneuvers previously mentioned and such maneuvers are becoming increasingly popular. How-

ever, the inventors have recognized that a risk is posed by the inadequate consideration of hemodynamic and cardiac implications. It is advisable to monitor parameters associated with the mechanics of the patient's blood circulation (i.e., hemodynamic parameters) such as the arterial blood pressure or the cardiac output or both and to end or alter the maneuver if there is a significant change in the value(s) of the monitored parameter(s).

Various procedures, also known as ventilation maneuvers, that alter the operation of a device or apparatus that is providing mechanical ventilation to a patient, may also be performed by the system described above. One example of a ventilation maneuver is a lung recruitment maneuver to re-expand collapsed lung tissue. Types of lung recruitment maneuvers may include, but are not limited to, regular sighs, sustained inflations, successively increased PEEP, and successively increased inspiratory pressure, or combinations thereof. A maneuver as used herein and in the claims comprises a procedure that provides signals that alters the operation of a device or apparatus (e.g., ventilator) that is providing mechanical ventilation to a patient. A hemodynamic parameter as used herein and in the claims comprises a blood related parameter that may include, for example, cardiac output and blood pressure (of different types). A regular sighs lung recruitment maneuver as used herein and in the claims comprises a controlled increase in the tidal volumes, PEEP or inspiratory pressure during a small number of successive assisted breaths produced at regular intervals. A sustained inflations lung recruitment maneuver as used herein and in the claims comprises continuous elevated airway pressure (above PEEP) applied for a specified time, typically up to 40 seconds but sometimes longer. A successively increased PEEP lung recruitment maneuver as used herein and in the claims comprises progressively increasing PEEP with each breath, or every few breaths, up to a maximum PEEP. A successively increased inspiratory pressure lung recruitment maneuver as used herein and in the claims comprises progressively increasing inspiratory pressure with each breath, or every few breaths, up to a maximum inspiratory pressure.

Another example of a ventilation maneuver is a low flow PV maneuver to determine appropriate ventilator settings. A low flow ventilation maneuver as used herein and in the claims comprises controlled inflation and deflation of a lung with a low constant flow in order to recruit the lung and determine characteristics derived from the recorded elastic properties of the lung while keeping the flow as low and constant as possible.

In one embodiment of the present invention, while the system is executing a ventilation maneuver under the control of the central processor **220** through a patient treatment module that is configured to control and communicate with the ventilator **250**, the patient monitor **210** monitors the arterial blood pressure and/or the cardiac output. If one or both of these parameters fall below a respective threshold while the pressure in the thorax is increasing, the maneuver is limited or aborted (i.e., terminated) by the central processor **220** and/or the central processor **220** provides an alarm. As used herein, limiting a maneuver refers to switching to low flow expiration while continuing the maneuver, and aborting a maneuver refers to immediately relieving the airway pressure to the PEEP. As is well-known, there is a trade-off between aborting or limiting a maneuver. Aborting a maneuver has the benefit of providing a rapid relief of pressure in the thorax favoring a rapid restoration of the arterial pressure, while limiting a maneuver has the competing benefit of not overstraining a possibly pre-damaged heart.

In one embodiment, a user configures the action (limit or abort) to be taken by the system when the parameter(s) fall below their respective thresholds. In another embodiment, the system also receives information regarding the ST segment from the patient monitor **210**, and automatically determines the action (limit or abort) based on the amount that the arterial blood pressure and cardiac output parameter(s) have fallen and also on the ST segment information. As is well-known, a typical ECG waveform consists of a P wave, a QRS complex and a T-wave. The portion of the ECG waveform between the end of the QRS complex and the beginning of the T-wave is referred to as the "ST segment." It is also well-known that an elevated or depressed ST segment (relative to the baseline at the end of the QRS complex) may be an indication that the heart has been damaged. In such case, the maneuver should be gradually limited so as not to expose the heart to excessive preload due to the return flow of a large blood volume from the capacity vessels. FIG. **6** depicts steps that may be performed by such an embodiment of the present invention. In Step **1**, the system starts the maneuver. The arterial blood pressure and cardiac output parameters are tested by the system as shown in Steps **2** and **3**. If the arterial blood pressure falls more than X % or the cardiac output falls more than Y %, then the information regarding the ST segment is tested as shown in Step **4**. If the ST segment information indicates possible heart damage, then the central processor **220** limits the maneuver as shown in Step **5**. In some embodiments, the rate at which the maneuver is limited is based on the degree of estimated heart damage as indicated by the ST segment information. If the ST segment information does not indicate possible heart damage, then the fall in arterial pressure and cardiac output are again tested, as shown in Steps **6** and **7**, against higher thresholds, Z % and A %, respectively, where Z>X and A>Y. If either of the higher thresholds is exceeded, then the central processor **220** aborts the maneuver as shown in Step **8**. Otherwise, the maneuver is limited as shown in Step **5**.

The thresholds for the fall in arterial blood pressure and cardiac output and the desired response (limit, abort and/or alarm) may be adjustable by a user, and may be assigned defaults, such as a 50% fall in arterial blood pressure and 60% fall in cardiac output. In some embodiments, either or both of the arterial blood pressure and cardiac output parameters are averaged and/or their deviations from previous baselines are integrated over time before comparing to the thresholds. In one such embodiment, averaging is performed over a time interval of duration such that a fall in parameter value can be recognized quickly, e.g., within a heartbeat.

In some embodiments, the system will slowly reduce pressure when limiting a maneuver, so as not to expose the heart to excessive preload due to the return flow of a large blood volume from the capacity vessels. For example, if the heart is in poor condition, as indicated by the ST parameter and/or additional information available to the central processor **220**, then the pressure will be reduced slowly. Similarly, if the integrated value of the arterial blood pressure's deviation from a baseline over time is high, then the system will reduce the pressure more slowly.

One skilled in the art will understand that various devices that are capable of performing ventilation functions may be used in the system described above. For example, a ventilator may be used; similarly, a device that delivers anesthesia to the patient may also incorporate ventilation functions and thus may be suitable for use in the system.

The system described above may also be used to perform electrical impedance tomography (EIT). EIT may provide continuous, breath-to-breath, and beat-to-beat anatomical images of respiratory and cardiac dynamics and distribution,

respectively. More specifically, the physician may see and quantify areas of atelectasis and hyperinflation in the lungs and/or may see and quantify the output of the right ventricle and the deposition of blood in the lungs with each heartbeat. Electrodes for providing current and sensing voltage are applied to the patient and appropriate signals are applied to them to sense the conductivity of the respective portions of the body. From these readings, an anatomical image, or real-time series of images, may be synthesized. The display generator **222** (FIG. **4**) generates signals representing these patient anatomical images. In order to maintain the display of these images in real time, the interface between the processor **402** and the display generator **222** provides substantially real time bidirectional communications. These images may be displayed on the display devices **321** and **331** on the main control panel **320** and slave control panel **330**, respectively. These images may also be supplied to the larger display device **225** on the slave display panel **224**. The physician may optimize ventilation parameters to address V/Q mismatch in which lung compartments are either ventilated but not perfused, or perfused but not ventilated. Early intervention, available from EIT images, may prevent cascade of lung injury leading to acute respiratory distress syndrome (ARDS) and sepsis. Use of EIT also has the possibility to reduce the number of CT and X-ray images required, and the intra-hospital transport required for them.

Referring again to FIG. **5**, the embedded operating system **506** is configured to monitor the input/output ports, which may include the serial port, **416**, the USB port **418**, the expansion card port **422**, the Ethernet ports **404**, **406**, and/or the panel I/O ports **410** to detect when a hardware device is newly connected to the system. When newly connected hardware is detected, at least the portion of the software required by the system software **500** to interact with this new hardware is retrieved from a mass memory, installed in the RAM **414** and made available to the operating system **506** and the rest of the system software **500**. This operation is sometimes called "plug-and-play". The mass storage device may be local to the central unit **300**, or may be remotely located (i.e. at a central location in the hospital) in which case it is retrieved via an Ethernet connection. When the SPOC application **523**, **524**, **526** is retrieved and loaded into RAM **414**, the newly connected module **210**, **212**, **214**, **250**, **260** is coupled to it. The newly connected patient monitoring and/or treatment module **210**, **212**, **214**, **250**, **260** then is controlled by the central unit **300** and begins functioning.

As described above, a patient monitoring and/or treatment module **210**, **212**, **214**, **250**, **260** is sometimes removed from a central unit **300** in one location and reconnected to a central unit **300** at a different location (FIG. **3**, FIG. **4**). When, a patient monitoring and/or treatment module **210**, **212**, **214**, **250**, **260** is reconnected to a central unit **300**, the operating system **506** advantageously detects its presence and identifies the SPOC **523**, **524**, **526** required to control it. If the required SPOC **523**, **524**, **526** is already loaded, then it is coupled to the newly connected module **210**, **212**, **214**, **250**, **260**. If the required SPOC **523**, **524**, **526** is not already loaded, it is retrieved from a mass storage device, as described above.

A system described above integrates passive patient monitoring modules **210** (FIG. **3**) and active treatment modules **212**, **214**, **250**, **260** (infusion pumps, ventilators, anesthesiology equipment, incubators etc.) with a central unit **300** and associated system software **500** which receives physiological parameter data and operational status information from and supplies control information to both types of modules. The software **500** permits modules to be disconnected from, and reconnected to the central unit **300**. The software **500** also permits interoperation of two or more of the modules cooperatively. The system reduces human error, improves speed of automatic adaptation of treatment, and of adapting treatment where human intervention is involved. In addition, the system improves the speed and accuracy of generating alerts, which may be crucial in a critical care unit such as an operating room. The system also saves space and cost, combines and groups alarms, provides consolidated documentation, facilitates module transportation and facilitates user operation. It reduces the problems presented to a healthcare worker in having to control multiple independent pieces of equipment. Because the modules may bidirectionally communicate with each other, tasks of supplying monitoring parameters to therapeutic modules, previously done manually, are advantageously accomplished automatically reducing human error. The critical care system may employ rules and programmed instruction governing addition of modules to the system. The integrated critical care system advantageously also provides a consistent user interface in both look and feel for the patient monitoring and therapeutic and life sustaining modules. This facilitates user friendly operation and reduces training required to educate a healthcare worker to operate the system compared to individual modules.

TABLE 1

SW Component	Functions
SW Framework	Waveform support
	Parameters Signal Group Support
	Alarm Support
	Event Support
	Reporting Support
	Trend Support
	GUI Components
	Deployment Support
	Diagnostics
	Peripheral Support
	Help
	Screen Layout Support
	Safety and Availability
	Hospital Network and Interface and Support
	Critical Care Network Interface and Support
	Patient Area Network Support
	Security
	User/Setups Configuration Support
	Patient Data/State Support
	Lifetime Management
	Database
	Real-time Infrastructure
	Communication Mechanisms
	IT and Third Party App Support
	Etc
CPOC	Real-time Waveforms
	Real-time Measurements
	Real-time Alarm Behavior, Display and Control
	Home-screen
	Alarm Limits
	Trends
	Events
	Alarm History
	Remote/Bed to Bed View
	Calculations
	Strip Recordings
	Real-time Loops
	Real-time Flow Meters
	Demographics
	Patient Transfer
	Network Transfer
	Remote Control
	Monitor/Patient State Handling
	SW Option Handling
	Patient Context
	User Context
	Vital View
	Module/Patient Configuration/Setups

TABLE 1-continued

SW Component	Functions
	Patient Category
	Full Disclosure
	Application Selection and Configuration Tools
	Flight Recorder
	Wireless Control
	Remote Keypad Handling
	Battery Management
	Measurement Setup and Priority
	Message Management
	Print Screen
	Taskcards
	Localization
	Etc
Ventilation	PO1
Management and Gas	IntrPEEP
Monitoring SPOC	Sigh
	Suction
	Nebulize
	IMV (as example for a breathing mode)
	Recruitment
	Lung functions
	Smart Care
	NIV
	Monitor Respiratory System
	Insp/Exsp Hold
	NIF
	RSB
	RC
	CO2 Monitoring (including VCO and VDS)
	Leakage Compensation
	Nurse Call
	ILV
	HF
	Airway Temperature
	Flow and airway pressure monitoring
	Oxygen
	Localization
	Etc
Monitor SPOC	ST Measuring Points
	OCRG
	EEG Power Spectra
	Cardiac Output
	Wedge
	Monitor Reports
	Respiratory Mechanics
	Surgical Display
	MIB Management
	ECG Control
	Invasive Pressure Control
	SPO2 Control
	Respiration Control
	Body Temperature Control
	NIBP Control
	EEG Control
	Transcutaneous Blood Gas Control
	End Tidal CO2 Control
	Arrhythmia Control
	ECG Lead Management
	Fractional Inspired O2 Control
	MultiGas Control
	Export Protocol Management
	OR Mode
	Monitor Setup
	Nurse Call
	Auto Dual View
	Auto Source Switching
	Localization
	Etc
Anesthesia Gas	Air, oxygen, and N2O control
Mixing SPOC	Carrier gas selection
	ORC
	(Xenon)
	Fresh gas flow
	Low and minimal flow
	Monitors gas supply
	Consumption monitoring incl. Prices
	Agas control
	Warm-up
	Agas monitoring
	Plug and play of a-gases
	Inspiratory control
	Expiratory control
	MAK monitor
	Quantitative anesthesia
	Localization
	Etc
Fluid SPOC	TCI
	TIVA
	PCA
	Localization
	Etc
CDPOC's	Anesthesia
	No agas without gas flow
	Acone
	Open Lung Tool
	Electrical Impedance Tomography (EIT)
	Respiratory Systolic Variation Test (RSVT)
	NICO
	Lung Mechanics Calculation (LMC)
	Automatic Lung Parameter Estimator (ALPE)
	Advanced Cardiopulmonary Integration Screens
	BiPAP
	SMART Alarms
	SmartCare
	Localization
	Etc
Other Applications	IT
	ChartAssist
	Remote View
	MegaCare
	BU-IT
	Localization
	Etc
	Imaging
	2D
	3D
	Virtual Film Sheet
	Patient Browser
	Dicom Query/Retrieve
	Localization
	Etc
	Third Party
	MagicWeb
	Cypress
	Localization
	Etc.

What is claimed is:

1. A method for managing patient ventilator operation, comprising the activities of:

performing a ventilation maneuver using a patient treatment module;

receiving by a patient monitoring module data from at least one parameter sensor, said data representing at least one of arterial blood pressure, cardiac output, and ST segment level of a patient;

calculating a percent fall between first sensed data representing at least one of the arterial blood pressure and cardiac output and subsequent sensed data corresponding to the at least one of the arterial blood pressure and cardiac output using a central processor communicating and controlling the patient monitoring module and the patient treatment module;

comparing the percent fall to at least one of a selected first percentage threshold corresponding to arterial blood pressure and a selected second percentage threshold corresponding to cardiac output using the central processor;

in response to at least one of a fall in said arterial blood pressure exceeding the selected first percentage threshold and a fall in said cardiac output exceeding the

selected second percentage threshold, analyzing ST segment level of the patient using the central processor;

in response to said ST segment level indicating no heart damage, using the central processor to adaptively alter at least one of the selected first percentage threshold and the selected second percentage threshold to a selected third percentage threshold that is greater than the selected first percentage threshold or a selected fourth percentage threshold that is greater than the selected second percentage threshold; and

in response to said ST segment level indicating possible heart damage, using the central processor to adaptively alter said ventilation maneuver.

2. The method of claim **1**, wherein said adaptively altering said ventilation maneuver comprises at least one of (a) terminating the ventilation maneuver, (b) altering respiratory volume, and (c) altering respiratory pressure.

3. The method of claim **1**, wherein said data representing at least one of arterial blood pressure, cardiac output, and ST segment level of a patient is averaged.

4. The method of claim **1**, further comprising:

generating an alarm in response to the received data representing at least one of arterial blood pressure, cardiac output, and ST segment level of a patient.

5. The method of claim **1**, wherein the ventilator maneuver is at least one of a recruitment maneuver and a low flow positive ventilation (PV) maneuver.

6. The method of claim **5**, wherein the recruitment maneuver is selected from the group consisting of at least one of regular sighs, sustained inflations, successively increased positive end expiratory pressure (PEEP), and successively increased inspiratory pressure.

7. The method of claim **1**, wherein said step of adaptively altering said ventilation maneuver comprises limiting the ventilation maneuver at a rate based on a degree of estimated heart damage as indicated by said ST segment level.

8. A method for managing patient ventilator operation comprising:

performing a ventilation maneuver using a patient treatment module;

receiving by a patient monitoring module data from at least one sensor representing arterial blood pressure;

receiving by the patient monitoring module data from said at least one sensor representing cardiac output;

calculating a percent fall between first sensed data representing at least one of the arterial blood pressure and the cardiac output and subsequent sensed data corresponding to the at least one of the arterial blood pressure and the cardiac output using a central processor communicating and controlling the patient monitoring module and the patient treatment module;

comparing the percent fall to at least one of a selected first percentage threshold corresponding to arterial blood pressure and a selected second percentage threshold corresponding to cardiac output using the central processor communicating and controlling the patient monitoring module and the patient treatment module;

in response to the at least one of a fall in said arterial blood pressure exceeding the selected first percentage threshold and a fall in said cardiac output exceeding the selected second percentage threshold, analyzing received ST segment level of a patient using the central processor;

in response to said ST segment level indicating no heart damage, using the central processor to adaptively alter at least one of the selected first percentage threshold and the selected second percentage threshold to a selected third percentage threshold that is greater than the selected first percentage threshold or a selected fourth percentage threshold that is greater than the selected second percentage threshold; and

in response to said ST segment level indicating possible heart damage, using the central processor to limit said ventilation maneuver at a rate based on a degree of estimated heart damage indicated by said ST segment level.

9. The method of claim **8**, wherein at least one of the data representing the arterial blood pressure and the data representing the cardiac output is averaged.

10. The method of claim **8**, further comprising:

generating an alarm in response to the received data representing at least one of arterial blood pressure and cardiac output.

11. The method of claim **8**, wherein the ventilation maneuver is at least one of a recruitment maneuver and a low flow positive ventilation (PV) maneuver.

12. The method of claim **11**, wherein the recruitment maneuver is selected from the group consisting of at least one of regular sighs, sustained inflations, successively increased positive end expiratory pressure (PEEP), and successively increased inspiratory pressure.

13. The method of claim **8**, wherein said step of limiting the ventilation maneuver comprises switching to low flow expiration while continuing said ventilation maneuver.

14. A system for managing patient ventilator operation, comprising:

a patient monitoring module for receiving data from at least one sensor, said data representing at least one of arterial blood pressure, cardiac output, and ST segment level of a patient;

a patient treatment module for providing signals for adaptively altering a ventilation maneuver performed on the patient by a patient ventilator;

a central processor communicating and controlling the patient monitoring module and the patient treatment module, the central processor configured for

calculating a percent fall between first sensed data representing at least one of the arterial blood pressure and cardiac output and subsequent sensed data corresponding to the at least one of the arterial blood pressure and cardiac output;

comparing the percent fall to at least one of a selected first percentage threshold corresponding to arterial blood pressure and a selected second percentage threshold corresponding to cardiac output;

in response to at least one of a fall in said arterial blood pressure exceeding the selected first percentage threshold and a fall in said cardiac output exceeding the selected second percentage threshold, analyzing ST segment level data of the patient;

in response to ST segment level indicating no heart damage, adaptively altering at least one of the selected first percentage threshold and the selected second percentage threshold to a selected third percentage threshold that is greater than the selected first percentage threshold or a selected fourth percentage threshold that is greater than the selected second percentage threshold; and

in response to ST segment level indicating possible heart damage, adaptively altering said ventilation maneuver.

15. The system of claim **14**, wherein adaptively altering said ventilation maneuver comprises at least one of (a) termi-

nating the ventilation maneuver, (b) altering respiratory volume, and (c) altering respiratory pressure.

16. The system of claim **14**, wherein said data representing at least one of arterial blood pressure, cardiac output, and ST segment level of the patient is averaged.

17. The system of claim **14**,

wherein the central processor is further configured for generating an alarm in response to the received data representing at least one of arterial blood pressure, cardiac output and ST segment level of the patient.

18. The system of claim **14**, wherein the ventilation maneuver is at least one of a recruitment maneuver and a low flow positive ventilation (PV) maneuver.

19. The system of claim **18**, wherein the recruitment maneuver is selected from the group consisting of at least one of regular sighs, sustained inflations, successively increased positive end expiratory pressure (PEEP), and successively increased inspiratory pressure.

20. The system of claim **14**, wherein adaptively altering said ventilation maneuver comprises limiting the ventilation maneuver at a rate based on a degree of estimated heart damage as indicated by said ST segment level.

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